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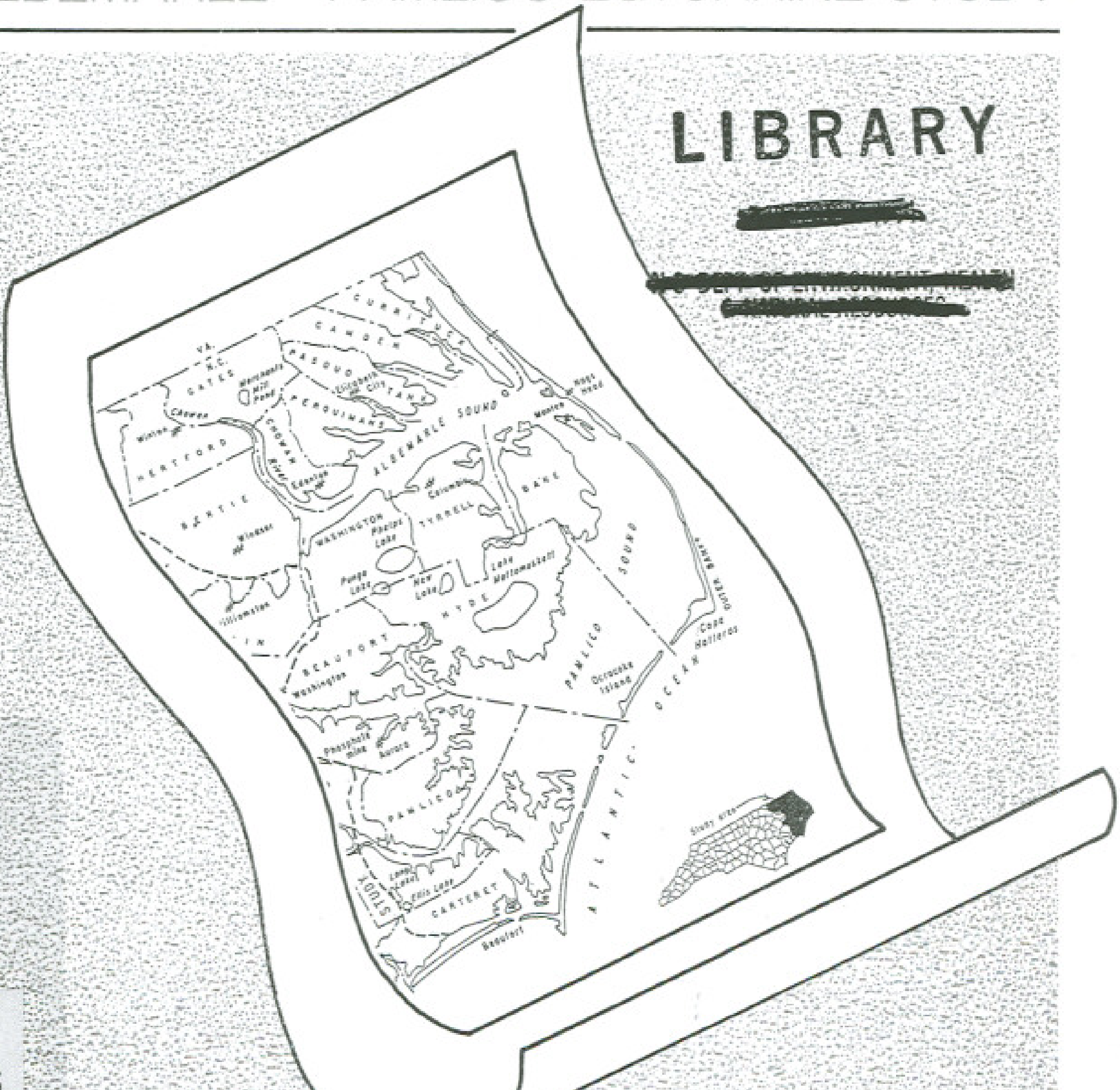
ABUNDANCE AND VIABILITY OF STRIPED BASS EGGS SPAWNED IN ROANOKE RIVER, NORTH CAROLINA. IN 1989

ALBEMARLE - PAMLICO ESTUARINE STUDY



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ABUNDANCE AND VIABILITY OF STRIPED BASS EGGS SPAWNED IN ROANOKE RIVER, NORTH CAROLINA, IN 1989

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Executive Summary

Sampling to estimate production and viability of striped bass eggs was conducted at Barnhill's Landing on the Roanoke River, North Carolina, from 15 April to 15 June 1989. Samples were taken by trailing paired nets at the surface from a small boat for five minutes every four hours for 60 days in the manner established and used by W.W. Hassler since 1959. A total of 4,722 eggs was collected in surface nets: first eggs appeared in samples on 16 April and continued sporadically until 9 June, when the last eggs were collected. Estimated striped bass egg production in the Roanoke River for 1989 was 637,919,162 (S.D. = 27,668,383) eggs. A potential major spawning activity at the end of April was terminated by high and prolonged reservoir discharge, which forestalled peak spawning until the last week in May. Three major spawning peaks were observed: 23-24 May, 26-27 May, and 31 May - 1 June. Seasonal egg production was 50% complete by 26 May, 80% complete by 29 May, and 99% complete by 2 June. Egg viability was estimated as 41.8%, the seventh lowest on record. Major egg deposition ensued when water temperatures reached 18°C. The majority of eggs (76.7%) were less than 10 hours old; an additional 18.5% were between 20 and 28 hours old, and less than five percent were 10 to 18 hours old. Approximately 89% of all eggs was collected at water temperatures between 18 and 21.9°C. Over half of the eggs were collected at water velocities ranging from 100 to 119.9 cm/second; an additional 22% were collected at 60-79.9 cm/second. An inverse relationship between egg viability and water velocity was evident. Less than one percent of all eggs were collected in waters of dissolved oxygen values less than 7.0 mg/L, and 90% of the eggs were in waters with pH values of 7.5 or higher. There was no significant difference in egg catches between surface and oblique collections. Results of this study and others conducted in 1981-1983, and 1988 clearly indicate that reservoir discharge from Roanoke Rapids dam influences striped bass spawning activity in the lower Roanoke River.

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Introduction

Striped bass (*Morone saxatilis*) inhabiting Albemarle Sound and its tributaries support important recreational and commercial fisheries in coastal North Carolina (Johnson et al. 1986; USDOI and USDOC 1986). The major spawning area for Albemarle Sound striped bass is located in the Roanoke River, which discharges into the western end of Albemarle Sound through several channels. Since the mid-1970s, these fisheries have suffered due to reduced numbers of harvestable adults. Population decline may be caused by a number of factors such as reduced egg viability (Hassler et al. 1981), poor food availability for larvae (Rulifson et al. 1986), and poor survival of juveniles on the nursery grounds of the western Sound.

Studies on egg abundance and viability have been conducted each year since the mid-1950s by Dr. W.W. Hassler and co-workers from North Carolina State University in Raleigh. The information gathered by these researchers spans nearly 30 years of complete records and is well-known as the best data base on striped bass spawning activity in North America. These daily records have been an extremely important source of information for reconstructing the historical spawning record in relation to exploitation, changes in fishing regulations, and man-induced changes in the flow regimen and water quality of the Roanoke River watershed. The retirement of Dr. Hassler in 1987 from actively pursuing his studies would have ended this valuable data base; however, funds provided by the Albemarle-Pamlico Estuarine Study (APES) to East Carolina University in the spring of 1988 allowed continuation of the study. This manuscript follows information obtained during the 1988 spawning season (Rulifson 1989), and summarizes the information obtained during the 1989 striped bass spawning season.

The manner in which water is released from dams on this watershed, and the subsequent physiological and behavioral effects on spawning striped bass, have been scrutinized closely at various times since construction of John H. Kerr Reservoir in 1952. This concern was one of the reasons for forming a Steering Committee for Roanoke River Studies in 1955. The Committee was composed of State, Federal, and private agencies and interests whose objective was to conduct a comprehensive study of the river in order to minimize multiple use conflicts (Hassler and Taylor 1986). The findings of the Committee were discussed in detail by Fish (1959). The co-operative Roanoke-Albemarle Striped Bass Studies were initiated in 1955 as part of the Steering Committee studies. Original support for these efforts was provided by the National Council for Stream Improvement, Weyerhaeuser Company, and Albemarle Paper Manufacturing Company. Weyerhaeuser Company continued their support of the studies after 1958 when the Steering Committee studies were terminated; cooperative field work was resumed in 1975 with the U.S. Fish and Wildlife Service and North Carolina Division of Marine Fisheries under the auspices of the Anadromous Fish Conservation Act (PL 89-304).

In the mid-1980s, water quality and watershed management of the lower Roanoke River basin were again key issues for several reasons: the initiation of the Albemarle-Pamlico Estuarine Study; the lawsuit between the State of North Carolina and the U.S. Army Corps of Engineers (COE) concerning the interbasin transfer of water for municipal use; the effort by the Federal government to establish a national wildlife refuge within the floodplain of the lower Roanoke River; and the continued decline of the Roanoke/Albemarle striped bass stock. These events all had the common concern of how the flow regime is managed by the system of reservoirs located in the Piedmont region of the watershed, especially during the spring season.

In 1988, an *ad hoc* group was formed to investigate the modification of Roanoke River instream flow below Roanoke Rapids Dam for striped bass and other downstream resources. The Roanoke River Water Flow Committee was comprised of 20 representatives of State, Federal, and university professionals. The purpose of the Committee was to gather information on all resources of the lower watershed and recommend a flow regime that was beneficial to downstream resources and their users. Striped bass as a resource received the most attention because of its great social and economic importance to this region, and because of the extensive data base established by Dr. Hassler. Detailed descriptions of the Flow Committee findings were presented by Manooch and Rulifson (1989) and Rulifson and Manooch (1990).

At the present time, the manner in which waters are released from Roanoke Rapids Dam is governed by a tri-party agreement involving the COE, Virginia Power, and the North Carolina Wildlife Resources Commission (NCWRC). Provisions for minimum flows from the reservoir were established by the Memorandum of Understanding signed in 1971, but no guidelines were given for maximum flows or for the manner in which the average daily discharge is derived. For example, under present guidelines the dam operator can double or cut in half the rate of discharge through the turbines every two hours to optimize on-demand hydropower generation. A discharge of 5,000 cfs (cubic feet per second) can increase to 10,000 cfs within two hours, and then to 20,000 cfs within three hours. These sudden changes in the flow regime result in dramatic changes in water depth on the spawning grounds within a several-hour period. Although these sudden and dramatic changes in flow are well-known, no studies have been conducted to determine how spawning is affected by this fluctuation in water level.

The study described herein was undertaken with several objectives in mind: 1) to continue the data base established by Dr. Hassler; 2) to develop a method to backcalculate Hassler's data in an egg density-per-unit-volume format (to compensate for radical changes in the flow regime); and 3) to correlate the intensity of striped bass spawning (as measured by egg production) with water releases from the reservoir at Roanoke Rapids, North Carolina. Only objectives 1 and 3 are addressed in this report. Objective 2 will require an additional year of study to ascertain the relationships among the physical parameters of volume, water velocity, river stage, and rate of net filtration.

Study Site Description

The Roanoke River is a major coastal floodplain river originating on the eastern slopes of the Appalachian Ridge in Virginia and discharging into the western end of Albemarle Sound in North Carolina (Figure 1, Appendix Table A-1). The watershed encompasses 9,666 square miles (25,033 km^2), making it the largest basin of any North Carolina estuary (Giese et al. 1979). Waters descend 2,900 feet from the origin to the estuary, a distance of 410 miles.

Flow of the Roanoke River is highly regulated by a number of reservoirs upstream: in Virginia, Smith Mountain Lake, Philpott Lake, Leesville Lake, John H. Kerr Reservoir, and Lake Gaston; and Kerr Reservoir, Lake Gaston and Roanoke Rapids Lake in North Carolina. Operation of the Roanoke Rapids hydroelectric facility located at River Mile (RM) 137 exerts direct influence on instream flow of the lower river; approximately 87% of the flow to the coastal watershed is provided by its discharge (Giese et al. 1979). Average annual discharge of the river at Roanoke Rapids, NC (USGS gage No. 02080500), is about 8,500 cfs. The watershed itself contributes approximately 50% of the freshwater input to Albemarle Sound.

The primary spawning ground for Albemarle striped bass is located in the Roanoke River between Halifax (RM 120) and Weldon (RM 130), North Carolina. The historical spawning grounds farther upstream were blocked by completion of the Roanoke Rapids Dam (RM 137) in 1955 (McCoy 1959). Spawning activity begins in April and is completed by mid-June (Hassler et al. 1981). Once spawned, the fertilized eggs develop to the hatching stage as they are transported downstream by currents. After hatching, the larvae are transported through the distributaries of the delta into the historical nursery grounds of western Albemarle Sound (Rulifson et al. 1988).

Methods

The field station in 1989 was located at Barnhill's Landing (RM 117), the site of Hassler's sampling efforts during the period from 1975 to 1981. This area is located (Appendix Table A-2) approximately three miles downstream of Halifax and about 12 river miles upstream of the Pollock's Ferry site used in the 1988 study (Figure 2). Initial water quality data were taken on 17 March, 23 March, 29 March, and 14 April 1989. Preliminary egg samples were taken on 6 April and 12 April. The actual study was initiated on 15 April and was terminated on 15 June 1989.

Procedures for field sampling and sample workup were identical to those used by Dr. Hassler to ensure compatibility of the data sets. The tables and figures presented herein are similar to Hassler's for purposes of comparison.

Striped bass eggs were collected in the same manner as that described by Dr. Hassler's annual reports (Hassler and others, 1961-1986) and as that used in the 1988 study (Rulifson 1989). Samples were taken six times daily at four-hour intervals (0200, 0600, 1000, 1400, 1800, and 2200 hours) by trailing paired 10-inch diameter nets constructed of 500-μm nitex mesh (6:1 tail-to-mouth ratio) from a small aluminum boat anchored in mid-stream. A solid cup attached to the tail of each net was used to retain collected eggs. Two collections of five-minute duration were made: the first collection six inches below the surface (Hassler's method), and the second collection in an oblique manner from the bottom to the surface. This procedure allowed comparisons of egg density at the surface with the abundance of eggs throughout the water column. A flowmeter with slow speed propeller was attached to the bongo frame so that the theoretical volume of water filtered could be estimated. This methodology produced two estimates of egg production: 1) an estimate of egg density per unit of water filtered; and 2) an estimate of total eggs in the cross-sectional area of the river (Hassler's method). The cross-sectional area of the river at the sampling site was determined for the range of water levels encountered during the study. River stage, air and water temperature, dissolved oxygen, conductivity, pH, total dissolved solids, and surface water velocity were recorded for each sample. Secchi visibility depth was recorded for all samples taken during daylight hours.

Samples were returned to the field station for immediate examination. Eggs collected by both nets were enumerated and averaged for each surface tow and each oblique tow. For each sample, all eggs were examined to determine viability and stage of development. Egg viability was determined as described by Hassler et al. (1981): each was examined to determine the status of the embryo, yolk and oil globules, and perivitelline space. Eggs were staged under a dissecting microscope using the criteria established by Bonn et al. (1976). Stage 1 included eggs less than 10 hours old. Stage 2 eggs were those 10 to 18 hours old. Stage 3 eggs were 20 to 28 hours old, and Stage 4 eggs were 30 to 38 hours old. Stage 5 were eggs 40 hours and older, and newly-hatched larvae. Stage of development was based on an assumed water temperature of 17°C; eggs spawned at water temperatures greater than this value will develop faster and hatch earlier (Hassler et al. 1981).

Data were entered into the mainframe computer at East Carolina University and analyzed using the Statistical Analysis System (SAS 1985). The estimated number of striped bass eggs passing the sampling station was calculated on a daily basis using the equation developed by Hassler:

$$N = 514.29\,XY,$$

where N = the estimated number of striped bass eggs spawned during the 24-hour period; X = the mean number of striped bass eggs collected per surface sample during the 24-hour period (12 samples maximum); and Y = the cross-sectional area of the river in square feet for mean river stage during the 24-hour period. The constant 514.29 was derived from the number of five-minute intervals in a 24-hour period (288) multiplied by the relationship of 1.0 square feet of river area to the mouth opening of the 10-inch diameter egg net (0.56 square feet, equaling a ratio of 1:1.785714). Only surface samples were used in the daily egg production estimates so that data were comparable to Hassler's database.

Statistical analysis of the egg count data was performed using the SAS UNIVARIATE procedure to determine distribution of the data. Normal probability plots indicated that transformation of the count data was required; natural log transformation reduced skewness and kurtosis better than square root transformation.

Results

Approximately 95% of the scheduled sampling trips were completed in 1989 (Appendix Table A-3). The remaining trips were incomplete or were not attempted due to unfavorable weather and equipment failure.

Egg Production and Viability

The estimated number of striped bass eggs produced in 1989 was 637,919,162 (n=61, S.D. 27,668,383) from a total of 4,722 eggs collected in surface nets. Initial samples were taken on 6 April and 12 April, but no eggs were observed in the nets. Eggs were first collected in surface nets at Barnhill's Landing on 16 April 1989 (Table 1). Whether spawning was initiated prior to this date is uncertain. Eggs were not observed again in surface nets until 28 April. Eggs were present in nets on a daily basis through 2 May, after which spawning activity nearly ceased. This near cessation of spawning activity by adult striped bass coincided with a sudden increase in reservoir discharge due to flooding conditions upstream. More information on this aspect will be presented later. After 17 May, spawning activity was continuous until 9 June, the last day in which eggs were collected in surface nets, for a continuous spawning window of 23 days. During this period, three major spawning peaks were observed: 23-24 May, 26-27 May, and 31 May - 1 June (Figure 3). Seasonal egg production was approximately 50% complete by 26 May, 80% complete by 29 May, and 99% complete by 2 June (Table 1, Figure 4). Sampling efforts were terminated on 15 June 1989.

Viability of striped bass eggs for 1989 was estimated at 41.8%, which was the seventh lowest estimate on record (Table 2). No seasonal change in egg viability was evident (Table 3, Figure 5); however, river stage had a small but significant role. Several statistical procedures were utilized in determining the relationship between viability and environmental parameters. Striped bass eggs were collected at the surface during 110 trips. Egg viability data from these trips were found to be normally distributed (Kolmogorov-D statistic = 0.077; P=0.106) using the UNIVARIATE procedure (SAS 1985). A correlation analysis was performed on all environmental variables to determine which variables were significantly related (alpha=0.05) and perhaps multicollinear. From results of the correlation analysis, nine variables were used in a stepwise regression procedure: PAGE (record indicating trip number); ATEMP (air temperature); WTEMP (water temperature); pH; DO (dissolved oxygen); COND (conductivity); TDS (total dissolved solids); WVEL (surface water velocity); and RSTAGE (river stage). Variables were entered into the model if the F statistic met a 0.15 level of significance. The best model was

$$\text{SURFVIA} = 59.6259 - 1.4797(\text{RSTAGE})$$

(df=97, F=19.29, $P<0.0001$, $r^2=0.17$, Mallow's statistic=3.62). The addition of PAGE (a sequential time factor) resulted in $R^2=0.19$ (Mallow's statistic=2.46), but PAGE itself was not significant in the model (F=3.18, P=0.078). These results indicate that river stage had a small but significant role in influencing striped bass egg viability just downstream of the spawning grounds in 1989.

River stage is directly related to reservoir discharge, which also affects other environmental variables. River stage was highly correlated with surface water velocity (n=339, r=0.85, P<0.0001), a relationship not surprising as the volume of water increases in the river with increased reservoir discharge. Water temperature was inversely related to both surface water velocity (n=344, r=-0.38, P<0.0001) and river stage (n=347, r=-0.35, P<0.0001); i.e., discharge of cool reservoir waters reduced the ambient river temperature. The relationship between water temperature and air temperature was not as strong (n=359, r=0.64, P<0.0001) as might be expected if air temperature alone was the sole influence on ambient river temperature.

A total of 4,237 eggs was examined throughout the season to determine stage of development. The majority of the eggs (76.7%, or 3,248 eggs) was less than 10 hours old. An additional 18.5% (785) of the eggs were between 20 and 28 hours old; less than five percent (201 eggs) were 10 to 18 hours old, and only three eggs were over 30 hours old. No post-hatch striped bass larvae were encountered in samples.

Water temperatures ranged from 13.0 to 24.5°C throughout the study; spawning was initiated when water temperatures reached 18°C (Figure 6). Spawning ceased in early May coinciding with a large water release from Roanoke Rapids Reservoir and a drop in water temperature below 18°C. Entry of a cold front at this time (Figure 7) resulted in continual rain (Figure 8) and runoff into the watershed. Spawning resumed in late May after a period of high but stable instream flow and a gradual rise in water temperature to 18°C. The correlation coefficient for the water temperature-air temperature relationship was 0.64 (n=359; P=0.0001). An inverse relationship of water temperature and river stage was evident (r= -0.352; n=347; P=0.0001). Data indicated that river waters heated more quickly under low flow conditions and were cooler under high flows from the release of cooler reservoir waters. Most eggs (89%) were collected at water temperatures ranging between 18 and 21.9°C (Table 4). Only three percent of the eggs were collected at temperatures less than 18°C, a result of adults still in the act of spawning at the time of the high volume water release from the reservoir in early May. An additional eight percent were collected at temperatures ranging from 22.0 to 23.9°C. No trend in viability as a function of water temperature was observed (Table 4).

Surface water velocities ranged from a low of 39 cm/second during low flow on 4 June to a high of 137 cm/second recorded on 21 May 1989 (Figure 9). Although eggs were present in nets over the range of velocities encountered during the study, over half were collected at surface water velocities between 100 and 119.9 cm/second (Table 5). An additional 22% were collected at water velocities from 60 to 79.9 cm/second. An inverse relationship between egg viability and water velocity was evident. Nearly five percent of all eggs were collected at water velocities of 120 cm/second or higher; the average viability was only 24% (Table 5). Greatest average viability (52%) was noted at lowest water velocities. A high positive correlation (r=0.854; n=339; P=0.0001) between water velocity and river stage at Barnhill's Landing was evident.

The high variability in surface water velocity can be attributed in part to the water release schedule at Roanoke Rapids Dam. Heavy spring rains in 1989 resulted in high flows during March; on-demand hydropower generation was evident from the USGS hourly flow records at Roanoke Rapids (Figure 10). Beginning 1 April, the COE implemented the Negotiated Flow Regime recommended by the Roanoke River Water Flow Committee (Manooch and Rulifson 1989, Rulifson and Manooch 1990). The schedule provided a step-down flow range from 1 April to 15 June which was designed to more closely represent the historical river flow prior to impoundment (Kerr Reservoir construction was started in 1950). The Corps of Engineers was forced to deviate from the Negotiated Flow Regime because of greater than normal rainfall and heavy inflow to Kerr Reservoir during the periods of 10-14 April and 2-29 May (20,000 cfs operation), and 1-2 June and 11-15 June (15,000 cfs operation).

In general, secchi disk visibility (Figure 11) and total dissolved solids (Figure 12) did not fluctuate greatly during the study. However, several points can be made about secchi disk visibility data. A substantial decrease in visibility was noted for the last days in April and beginning of May. This decrease coincided with heavy rainfall events (Figure 8) in the local area below the reservoir, and resulted in increased input of sediment-laden waters into the Roanoke River (which at the time was experiencing flows of 5,000 to 6,000 cfs, Figure 10). Several days later when water release was increased from Roanoke Rapids Reservoir in response to heavy inflow upstream, waters flowing past Barnhill's Landing actually increased in surface visibility as the river stage changed a dramatic 15 feet (Figure 13). A similar drop in water clarity occurred in early June, when river flow was about 4,000 cfs (Figure 11).

Conductivity of Roanoke River waters flowing past Barnhill's Landing was low throughout the study, usually varying between 70 and 100 µS (Figure 14). However, a dip in conductivity readings to 40 µS was evident at the end of April during the low flow period just prior to the major water release event from Roanoke Rapids Reservoir.

Patterns of egg distribution in samples compared to sampling time reflected the time of travel downstream from the spawning grounds. For the entire spawning season, egg collection was lowest at 1400 and 1800 hours. At 2200 hours, the number of eggs in nets increased with peak occurrence at 0600 and 1000 hours (Table 6). In 1989 some spawning was observed at Barnhill's Landing on several occasions. However, most recreational fishing activity was concentrated between Halifax and Weldon during the period of peak spawning activity. Predicting the actual site of major spawning activity is difficult. Over 75% of the eggs were less than 10 hours old (based on development at 17°C) and caught in surface water velocities of 100-120 cm/second. Assuming an average water velocity of 100 cm/second (3.28 ft./second), major spawning activity could have occurred anywhere between 2 and 20 river miles (at the dam) upstream of Barnhill's Landing.

Levels of dissolved oxygen in Roanoke River waters remained above 7.0 mg/L throughout the study, but a general decrease was evident between April and June (Figure 15). Less than one percent of striped bass eggs were collected in waters containing dissolved oxygen levels less than 7.0 or greater than 8.9 mg/L (Table 7).

Acidity of the waters passing Barnhill's Landing ranged from 6.5 to 8.8 but remained above 7.0 throughout much of the study (Figure 16). A noticeable drop in pH was recorded late April and early May concurrent with low flows of the Roanoke River and high inflow from locally heavy rainfall. Approximately 90% of striped bass eggs were collected in waters with pH values of 7.50 or greater (Table 8). Greatest viability was observed at pH values ranging from 6.75 to 7.24; the total numbers of eggs collected in this range are too few to determine statistical significance of the trend.

Vertical Heterogeneity

During each sampling trip, paired-net egg samples were taken both at the surface and in an oblique manner for five-minute periods so that potential bias in the vertical distribution of eggs could be quantified. Egg production for each trip was calculated by using the ratio of the opening of the egg net to the estimated cross-sectional area of the river multiplied by the average number of eggs caught in either the surface nets or in the oblique nets during the five-minute tow.

A total of 9,829 eggs was collected in all nets. Surface net A collected 2,336 eggs (n= 344; mean = 6.81; S.D. = 23.57) and surface net B collected 2,553 eggs (n = 344; mean = 6.96; S.D. = 22.17). An analysis of variance of the paired net count (raw) data revealed that the surface egg data were skewed and not normally distributed. A signed rank test on natural log transformed data showed that the difference of egg counts between surface nets was significantly different from zero (n=344, P=0.029); i.e., surface net B was consistent in catching more eggs than surface net A even though the total **seasonal** difference between nets was only 217 eggs.

A similar comparison of oblique net egg collections indicated no significant difference in egg counts between paired nets. A total of 2,297 eggs (n = 339; mean = 6.80; S.D. = 20.66) was collected in oblique net A, and 2,810 eggs (n = 339; mean = 8.13; S.D. = 30.91) in oblique net B. Again, analysis indicated that the data were skewed and not normally distributed. The data were transformed using the natural log, and a signed rank test revealed that differences in catch between the two nets were not significantly different from zero (n=339, P=0.479).

In 1989 egg collections in surface nets and oblique nets were not significantly different. A natural log transformation on average surface net data and average oblique net data showed that differences between egg counts with depth were not significantly different from zero (n=339, P=0.082).

A comparison of egg viability estimates between surface net samples and oblique net samples indicated no significant difference in egg viability with depth (n=92, P=0.864).

Egg production estimates on a per trip basis were calculated for surface samples, oblique samples, and all samples combined. When spawning activity was low, differences in egg production estimated as a function of depth appeared large (Table 9). For example, on 3 May 1989 no eggs were collected in surface nets and therefore no egg production was estimated for that day using Hassler's method. However, egg production estimated from oblique samples for the same day resulted in a total of 20,225 for the six trips, or 1,003,728 eggs for the 24-hour period (Table 10). When spawning activity intensified later in the season, these differences in estimates were relatively smaller and not significantly different statistically.

The two methods of calculating daily egg production (Table 10) -- the Hassler method and the Trip method -- were compared statistically for surface samples, oblique samples, and all samples combined. For surface samples, Hassler's method yielded a 1989 egg production estimate of 637,919,161 (S.D. 27,078,836), and the Trip method estimated a seasonal total of 637,110,340 (S.D. 27,668,383). Analysis (sign rank test) on natural log transformed data indicated no significant difference (n=61, P=0.690) in the two methods. For oblique samples, the Hassler method estimated a total egg production of 720,331,787 (S.D. 31,057,829), while the Trip method estimated 720,161,682 (S.D. 31,057,571), again not statistically different (n=61, P=0.604, log transformed data). Using all data collected by both surface and oblique nets, egg production estimates by the two methods were not significantly different (n=61, P=0.580, log transformed data).

Discussion

Water Temperature, River Flow, and Spawning

The tendency for a fish species to be successful and thrive is ultimately determined by the ability of the individuals in the population to reproduce successfully in a fluctuating environment, thereby maintaining a viable population. Each fish species thrives under a unique set of ecological conditions, so the reproductive strategy is also unique with special anatomical, behavioral, physiological, and energetic adaptations (Moyle and Cech 1982).

The role of temperature as an environmental cue for fish reproduction is well documented. Seasonal changes in temperature and light are often the most important cues physiologically because they can act directly or indirectly on hormonal glands to control development of the gonads (Moyle and Cech 1982). The onset of striped bass spawning occurs later in the season with increasing latitude, starting in February (Florida) and continuing through June or July along the southern shore of the Gulf of St. Lawrence and the lower St. Lawrence River (Rulifson et al. 1982). Duration of spawning activity ranges from eight days (Hollis 1967) to 44 days (May and Fuller 1965), although Hassler, Trent and Gray (1963) reported spawning activity in the Roanoke River over a 51-day period in 1963.

Striped bass eggs have been collected at water temperatures ranging from a low of 10°C (Nichols 1966) to 25°C (Merriman 1941), although striped bass spawning from North Carolina southward generally begins at 13°C or higher and ends around 22°C (Rulifson et al. 1982). A variety of spawning temperatures for Roanoke striped bass have been reported: 13°C to 21.7°C with a peak from 16.7°C to 19.4°C (Shannon and Smith 1968, Shannon 1970, Street 1975). Hassler et al. (1981) reported that approximately 90% of spawning activity in the Roanoke River occurs from 15.4°C to 20.3°C. In 1988, Rulifson (1989) reported that over 94% of all eggs were collected at Pollock's Ferry (River Mile 105) between 18°C and 23.9°C. These warmer temperatures are probably the result of solar heating of river waters with increasing distance downstream from Roanoke Rapids Dam. In 1989, most eggs collected at Barnhill's Landing were in waters between 18°C and 21.9°C (Table 4). In both 1988 and 1989, a rise in water temperature to 18°C triggered the major portion of spawning activity.

The influence of water release from the reservoir on downstream water temperatures was evident in 1989. The cooler waters from the reservoir released in high volume into a low-flowing river warmed by solar input decreased the water temperature of the stream. This phenomenon helps explain a long-standing theory predicated on observations supplied by fisheries biologists and sport fishermen: spawning activity of striped bass is triggered by dropping water levels and is stopped or reduced by rising waters. Egg collections and stage of development were compared to river flow as measured by the USGS gage at Roanoke Rapids. First eggs appeared in samples on Sunday, 16 April one day after reservoir discharge decreased from about 20,000 cfs to approximately 9,000 cfs (Figure 17). Stable flows the week of 16 April resulted in water temperatures increasing throughout the week (Figure 6) and brief spawning activity near the end of the week. During the week of 23 April water releases were somewhat more variable, dropping several thousand cfs late Tuesday evening and resulting in eggs collected in nets on Wednesday. Flows increased approximately 5,000 cfs late Wednesday evening and remained at approximately 11,000 cfs until early Thursday evening when flows dropped to about 6,000 cfs for the remainder of the week (Figure 17). Water temperatures increased to 18°C at this time (Figure 6), resulting in continual, moderate spawning activity through the weekend and into Monday, 1 May. The heavy inflow to the reservoir system upstream necessitated water release from reservoir storage on 1-2 May, resulting in an increase in river flow from about 5,600 cfs to over 20,000 cfs within the two-day period. As water temperatures dropped, spawning activity ceased (Figure 17). A similar cessation of spawning activity in the Sacramento River system caused by sudden drops in temperature or the passage of cold fronts was noted by Calhoun et al. (1950).

Sampling Site and Egg Viability

Bias in the estimate of egg viability due to sampling location was suspected after obtaining a high viability estimate of 89% in 1988 at Pollock's Ferry (RM 105) and a low of 42% at Barnhill's Landing (RM 117) in 1989. Additional evidence was provided by Hassler's data base as reported in Table 2. In 1959-1960, the average egg viability at Palmyra (RM 78.5) was nearly 93%, but in both years data for only a portion of the season were obtained. During the years that Hassler sampled upstream at Halifax (RM 121) near the spawning grounds (1961-1974), egg viability averaged 88.53% (S.D. 5.77, n=14). In 1975, egg viability dropped to about 56%, which also happened to coincide with a change in sampling location downstream at River Mile 117. For the seven years of data collection at Barnhill's Landing, egg viability averaged 51.08% (S.D. 11.75). In 1982, Hassler moved operations one mile upstream to Johnson's Landing and from 1982-1987, the average egg viability was only 49% (S.D. 20.22, n=6).

Based upon these observations, I hypothesized that sampling too close to, or too far away from, the spawning grounds could overestimate the yearly egg viability estimate. Biologically, this rationale is sound. Sampling too close to the spawning grounds may not allow adequate time for eggs to physically show evidence of nonviability: e.g., cloudiness, broken membranes, nonfertilization. Sampling too far downstream may provide too much time between egg release and egg collection in nets, thus allowing nonviable eggs to be removed from the water column by bursting, predation, sinking, or transport to floodplain areas. The bulk of those eggs remaining within the water column should be viable. Following this line of reasoning, the sampling location providing the best estimate of egg viability should be somewhere in between (i.e., Johnson's Landing or Barnhill's Landing). To test this hypothesis would require two or three sampling crews at the upstream (Halifax), middle (Barnhill's Landing), and downstream (Pollock's Ferry or Palmyra) sites collecting eggs at the same frequency for the entire spawning season.

Two egg studies of a similar nature conducted at different locations in 1981, 1982, and 1983 provided the opportunity to test the hypothesis indirectly. Hassler conducted his 1981 egg study at Barnhill's Landing (Hassler, Luempert and Mabry 1982) and at Johnson's Landing in 1982 and 1983 (Hassler and Taylor 1984). The N.C. Wildlife Resources Commission monitored egg production at Johnson's Landing in 1981 (Kornegay 1981), and at Pollock's Ferry in 1982 (Kornegay 1983) and 1983 (Kornegay and Mullis 1984).

The methods and equipment used in the NCWRC studies were different than that used by Hassler; an understanding of data collection is necessary prior to comparing the two data sets. Hassler's methodology and gear was explained previously. Kornegay (1981) collected eggs with two 0.5-m diameter 505-μm mesh plankton nets. One net was mounted on each side of the boat in a push net frame described by Tarplee et al. (1979). Sampling frequency was initially three times a day; maximum frequency was every four hours during peak spawning activity. The nets were pushed through the water facing upstream at a speed such that the boat remained stationary or advanced slightly in relationship to the shore. Effort was six minutes initially, but was reduced to three minutes when spawning activity was greatest. The numbers of eggs collected were converted to numbers per 100 cubic meters of water filtered. Determination of egg viability was similar to the Hassler method. The same field procedures were used in 1982 and 1983 (Kornegay and Mullis 1984). Data sets for the following comparisons are presented in the Appendix (Tables A-6 and A-7).

In 1981, Hassler (Hassler, Luempert and Mabry 1982) sampled from 29 April to 29 May and reported an egg viability of 73.7% (Table 2). Kornegay's efforts one mile downstream began on 21 April and ended 15 May, resulting in an egg viability estimate of 68.97%. These two egg viability estimates are within five percent and so appear similar. The similarity is not so striking when daily viability estimates are plotted (Figure 18). With one exception, daily egg viability estimates for Johnson's Landing were consistently higher than for the downstream Barnhill's Landing site. These results support the egg viability bias hypothesis described above. However, the daily egg production data are very similar and show peak spawning activity around 29 April and again around 9-15 May (Figure 18). Coincidentally, these spawning activity peaks occur just after sudden changes in river flow: a 4,000 cfs increase on 22-24 April and a similar decrease on 7-8 May (Figure 19). Minor spawning peaks in mid and late May exhibit this similar pattern.

In 1982, Hassler (Hassler and Taylor 1984) sampled at Johnson's Landing from 3 May to 2 June; spawning activity had started prior to sampling efforts. Hassler's egg viability estimate for 1982 was 71.93% (Table 2). Thirteen miles downstream at Pollock's Ferry, Kornegay (1983) sampled from 20 April to 14 May and obtained an egg viability estimate of 76.47%, a value within five percent of the Hassler estimate. Again, the lower value obtained at Johnson's Landing and the higher value estimated downstream at Pollock's Ferry fits the sampling location bias hypothesis.

However, visual inspection of the 1982 daily viability estimates shows a high degree of similarity between the two stations (Figure 20). Even though the sites are 13 miles apart, egg transport time may be as short as 7.6 hours, assuming a uniform water velocity of 2.5 feet/sec (75 cm/sec). Thus, egg viability estimates calculated on a daily, rather than per sample, basis may not be adequate to determine egg viability differences between the two sites. Both daily egg production estimates reveal similar patterns in spawning activity: peak spawning occurred approximately 9-11 May (Figure 20) just after river flow dropped from 11,600 cfs to about 6,300 cfs on 7-8 May (Figure 21). Kornegay (1983) attributed the spawning peak to increases in water temperature to 18.4°C.

In 1983, Hassler (Hassler and Taylor 1984) sampled at Johnson's Landing from 6 May to 12 June and estimated egg viability as 33.29% (Table 2). Kornegay and Mullis (1984) sampled at Pollock's Ferry from 24 April to 31 May and reported egg viability at 40.48%. Again, the higher egg viability estimate downstream supports the sampling location bias hypothesis.

Trends in daily egg viability data are obscured because of extensive flooding in the spring of 1983 (Figure 22), although higher daily egg viability later in the season seemed to coincide with lower river flow (Figure 23). Flow models by the U.S. Army Corps of Engineers indicate that the watershed floods under prolonged periods of 8,000 cfs river flow or more (M. Grimes, Wilmington District, Corps of Engineers, personal communication).

Similar to the 1981 and 1982 spawning seasons, peaks in 1983 striped bass spawning activity coincided with changes in river flow. During the latter half of April and early May river flows approached 26,000 cfs, then dropped to about 20,000 cfs on 7 May. The first, though minor, spawning peak was observed on 9 May. A second, slightly larger, spawning peak occurred on 15-17 May during a rather stable period of river flow. A third, larger peak on 24-26 May coincided with dropping water levels initiated on 25 May. The major peak spawn, which occurred on 30 May, coincided with lowest water levels of the season established two days earlier (Figure 23).

From the results of the independent studies conducted by Hassler and the NCWRC in 1981, 1982, and 1983, and the 1988 and 1989 studies funded by the Albemarle-Pamlico Estuarine Study, it is clear that spawning activity of Roanoke River striped bass is affected by reservoir discharge. The relationship between egg viability and success of juvenile recruitment to the year class is unclear. Ongoing studies of egg and larval transport, food abundance, and water quality should provide additional information to answer questions about environmental influences on striped bass recruitment.

Summary and Conclusions

1. The estimated number of striped bass eggs produced in the Roanoke River for 1989 was 637,919,162 (S.D.=27,668,383) from a total of 4,722 eggs collected in surface nets during the period 15 April to 15 June. Spawning prior to 15 April was undetermined.

2. In 1989, major spawning activity at the end of April ceased coinciding with high volume discharge from Roanoke Rapids Reservoir. Continued prolonged discharge forestalled major spawning activity until the last week in May at which time there were three peaks: 23-24 May, 26-27 May, and 31 May- 1 June. Seasonal egg production was 50% complete by 26 May and 99% complete by 2 June.

3. Major egg deposition was observed after water temperatures reached 18°C.

4. Egg viability for 1989 was estimated at 41.8%, the seventh lowest on record.

5. Most eggs (76.7%) passing Barnhill's Landing were less than 10 hours old. An additional 18.5% were 20-28 hours old, and less than five percent were 10-18 hours old. Only three eggs were over 30 hours old.

6. Most eggs (89%) were collected between 18 and 21.9°C, temperatures representing the bulk of those recorded during the study; only three percent were collected below 18°C. No trend in viability with water temperature was observed.

7. Over half of the eggs were collected in surface water velocities of 100-119.9 cm/second. An additional 22% were collected in waters flowing 60-79.9 cm/second. An inverse relationship between viability and water velocity was observed.

8. Over 99% of all eggs were collected at dissolved oxygen levels between 7 and 8.9 mg/L, values representing the majority of those recorded during the study.

9. Approximately 90% of all eggs were collected in waters of pH values 7.5 and higher, although greatest viability was observed at pH values between 6.75 and 7.24.

10. No significant difference in estimated egg production between surface and oblique methods was evident.

11. Based on data from 1988 and 1989, as well as comparisons of two independent egg studies conducted in 1981, 1982, and 1983, it is clear that reservoir discharge from Roanoke Rapids Dam influences spawning activity of striped bass.

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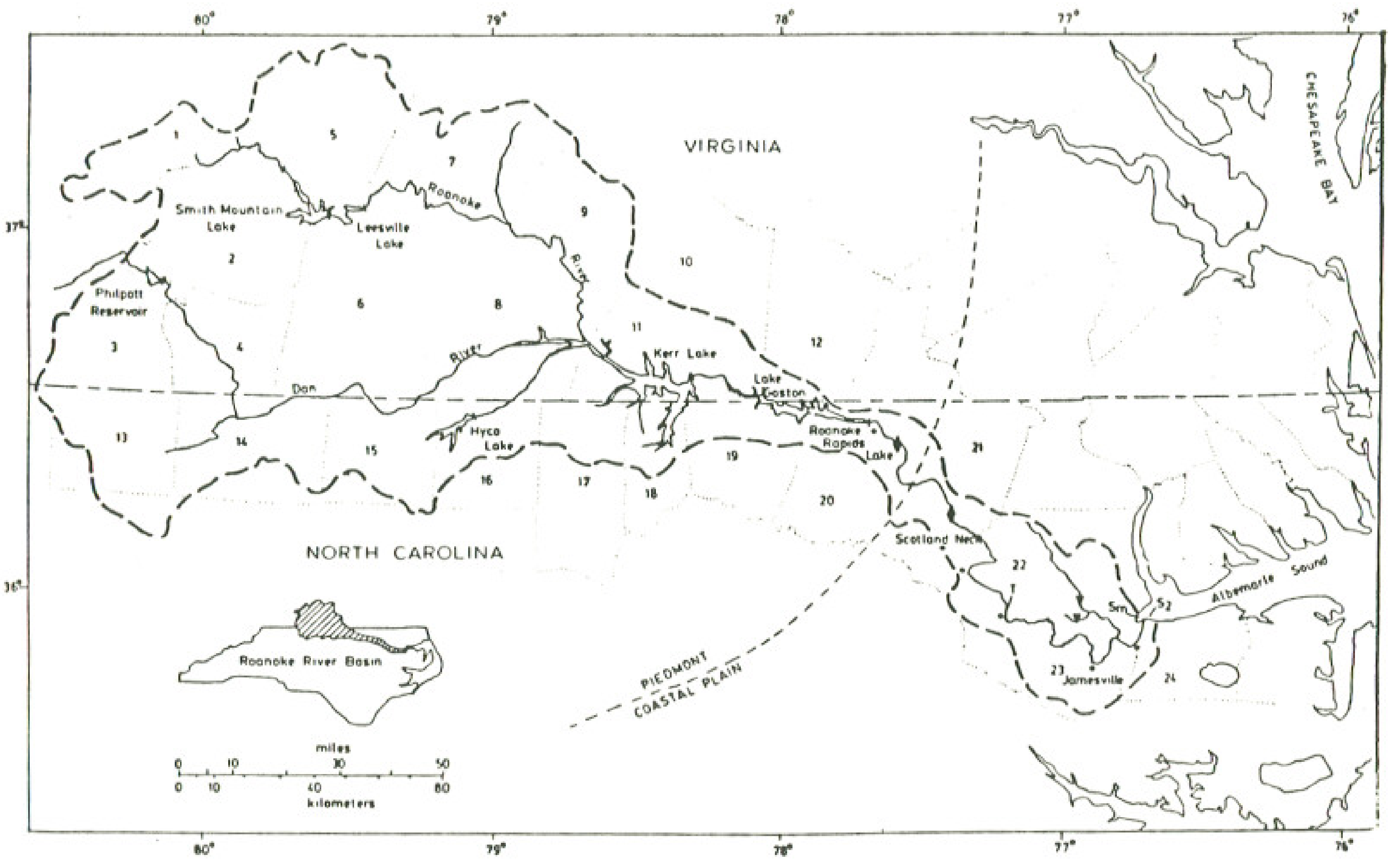


Figure 1. Drainage area of the Roanoke River Basin. Dashed line indicated approximate location of the Fall Line; diamonds=locations of USGS water quality and gaging stations; inverted triangle=USGS water quality station; T=upstream limit of tidal influence; S2=mean upstream intrusion limit of saltwater front (200 mg/L chloride); Sm=maximum upstream intrusion of saltwater front (Giese et al. 1979. Counties containing Roanoke watershed are enumerated and listed in Appendix Table A-1.

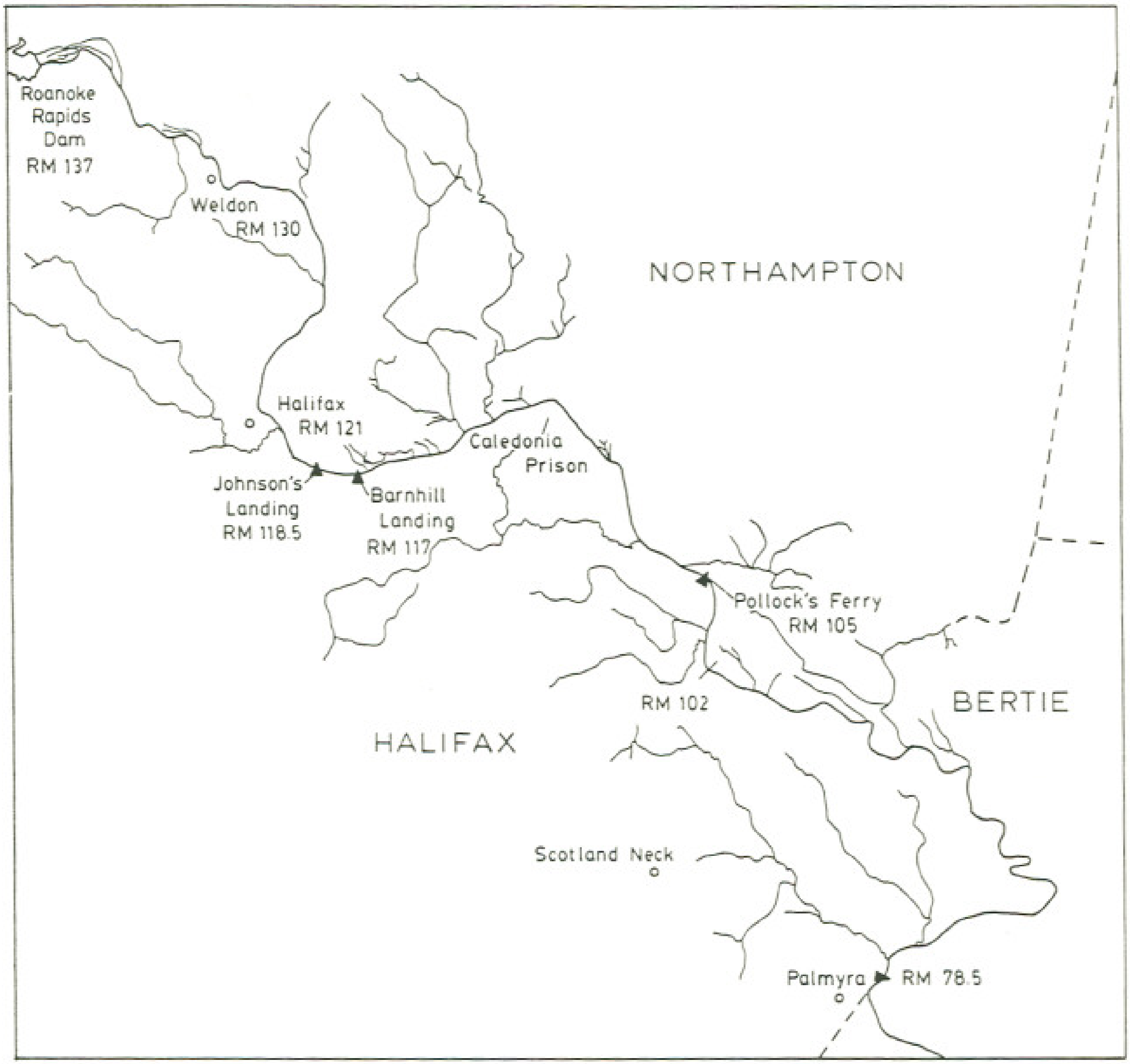


Figure 2. Roanoke River watershed downstream of Roanoke Rapids Reservoir showing the historical sampling stations for striped bass eggs: Palmyra (1959-60), Halifax (1961-74), Barnhill's Landing (1975-81, 1989), Johnson's Landing (1982-87), and Pollock's Ferry (1988).

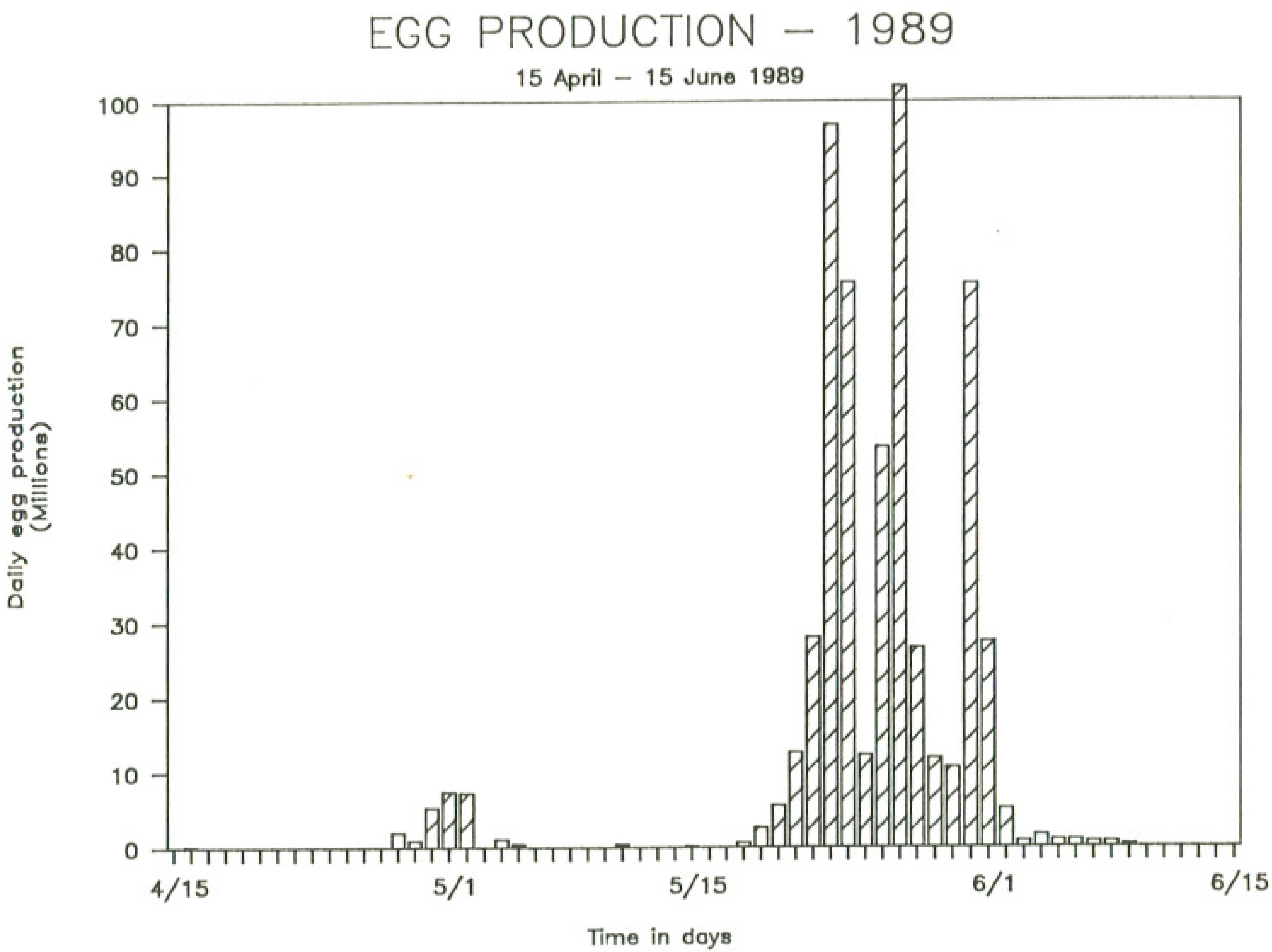


Figure 3. Estimated daily production of striped bass eggs in the Roanoke River based on samples collected at Barnhill's Landing, NC, for the period 15 April to 15 June 1989.

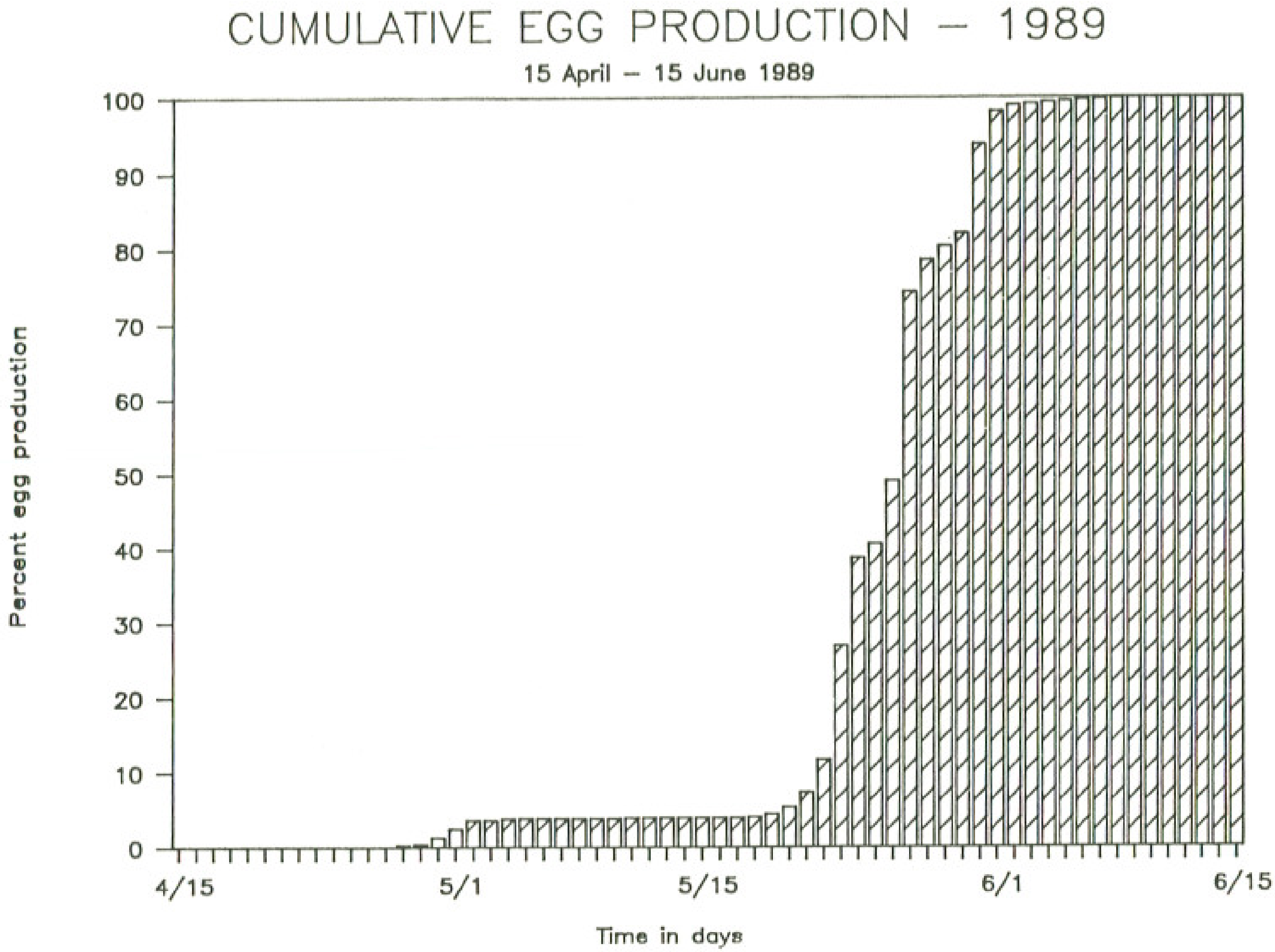


Figure 4. Estimated production of striped bass eggs in the Roanoke River based on samples collected at Barnhill's Landing, NC, in 1989, presented as percentage of total production.

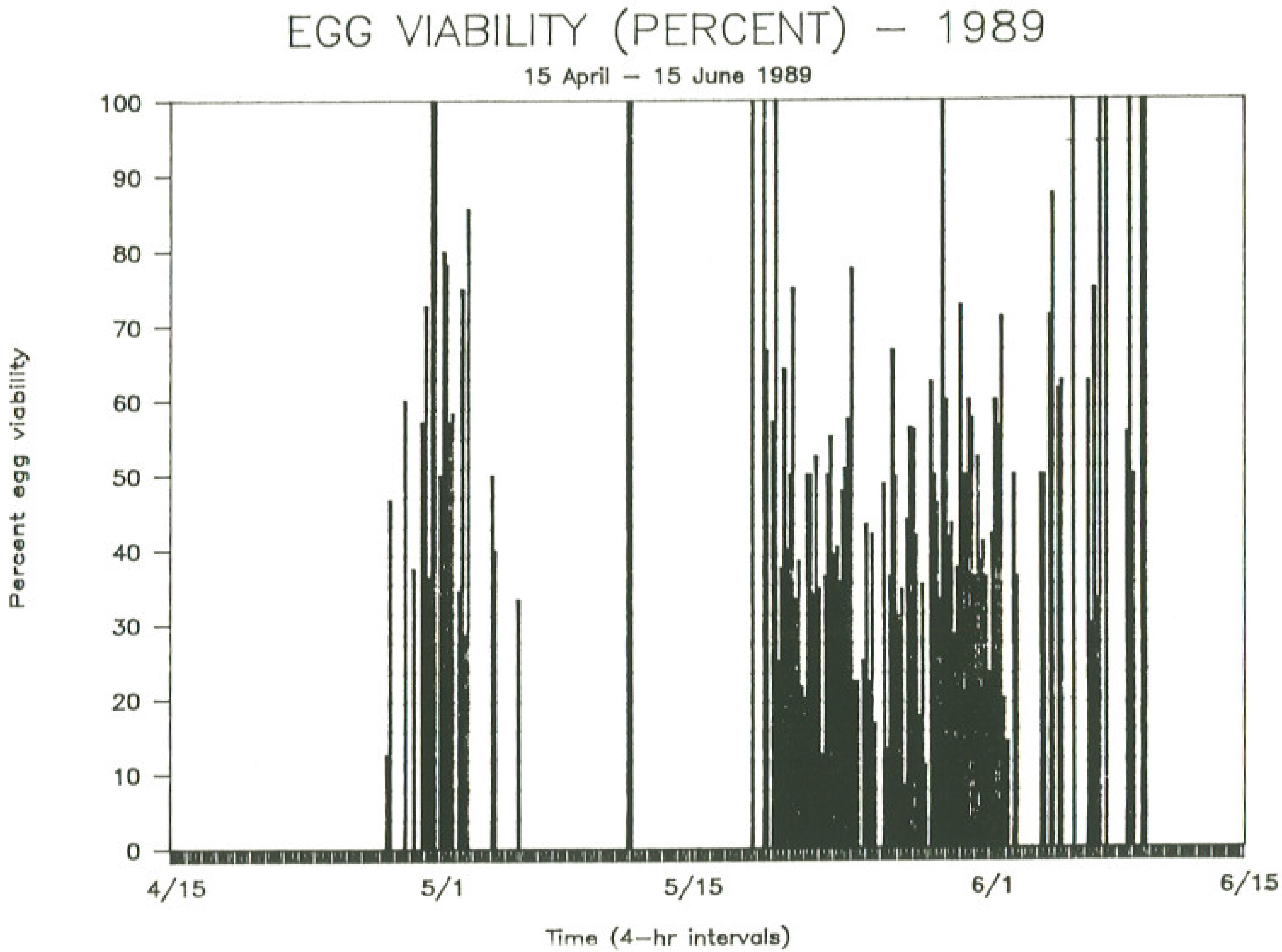
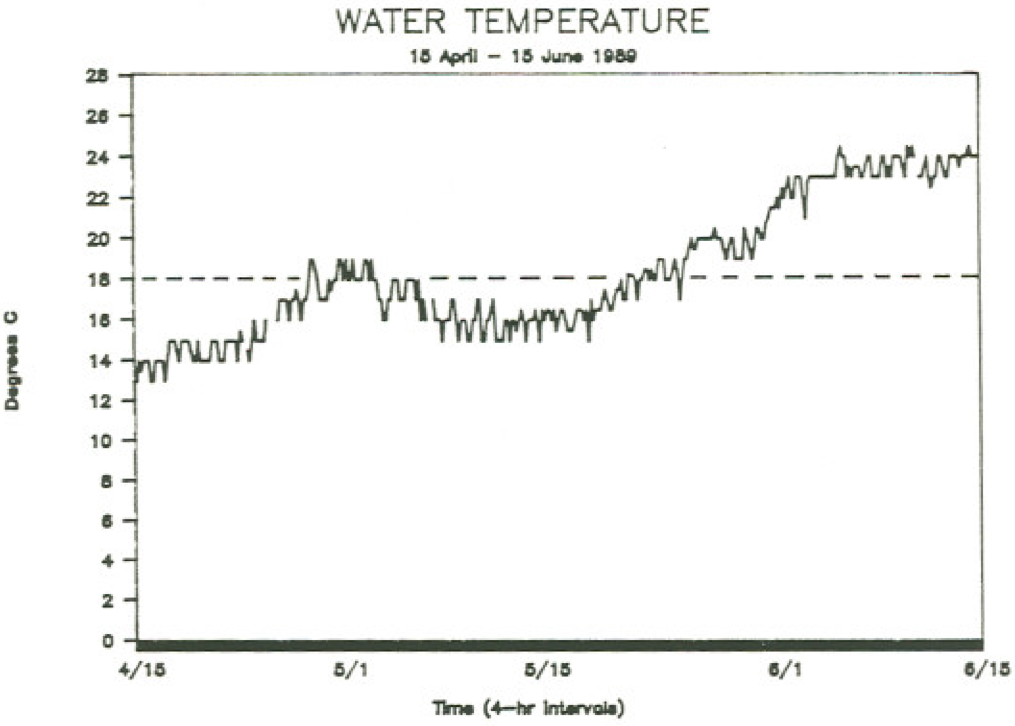


Figure 5. Daily viability estimates of striped bass eggs in the Roanoke River based on samples collected at Barnhill's Landing, NC, in 1989.



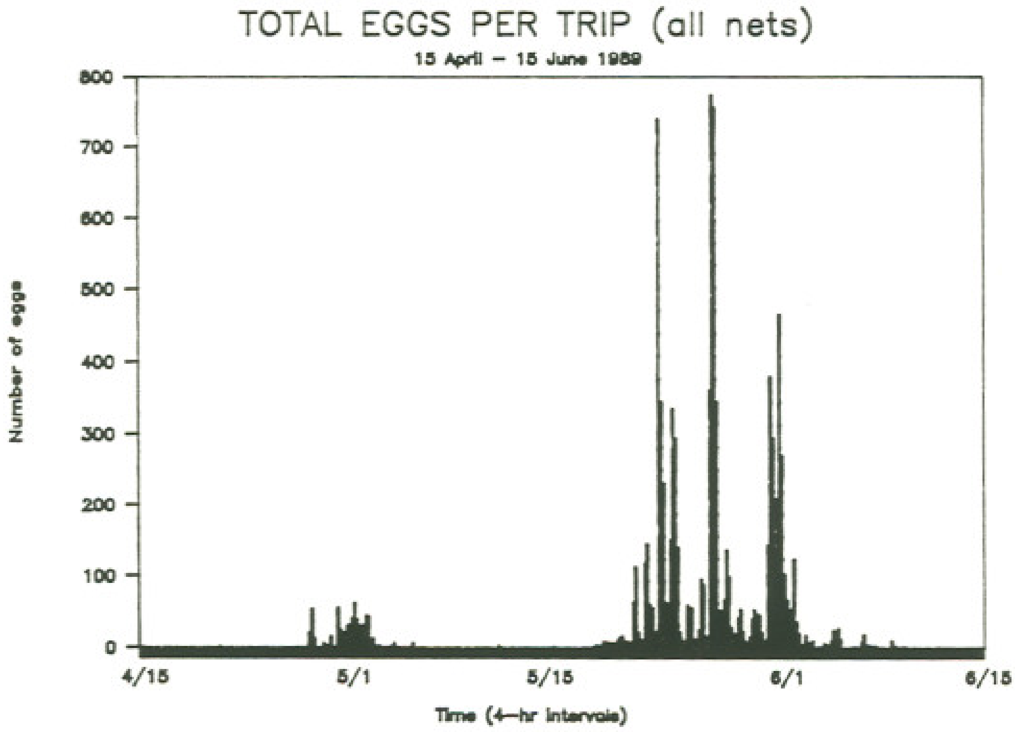


Figure 6. Number of striped bass eggs collected in all nets during each trip, and corresponding water temperatures (°C) at Barnhill's Landing, NC, for the period 15 April to 15 June 1989.

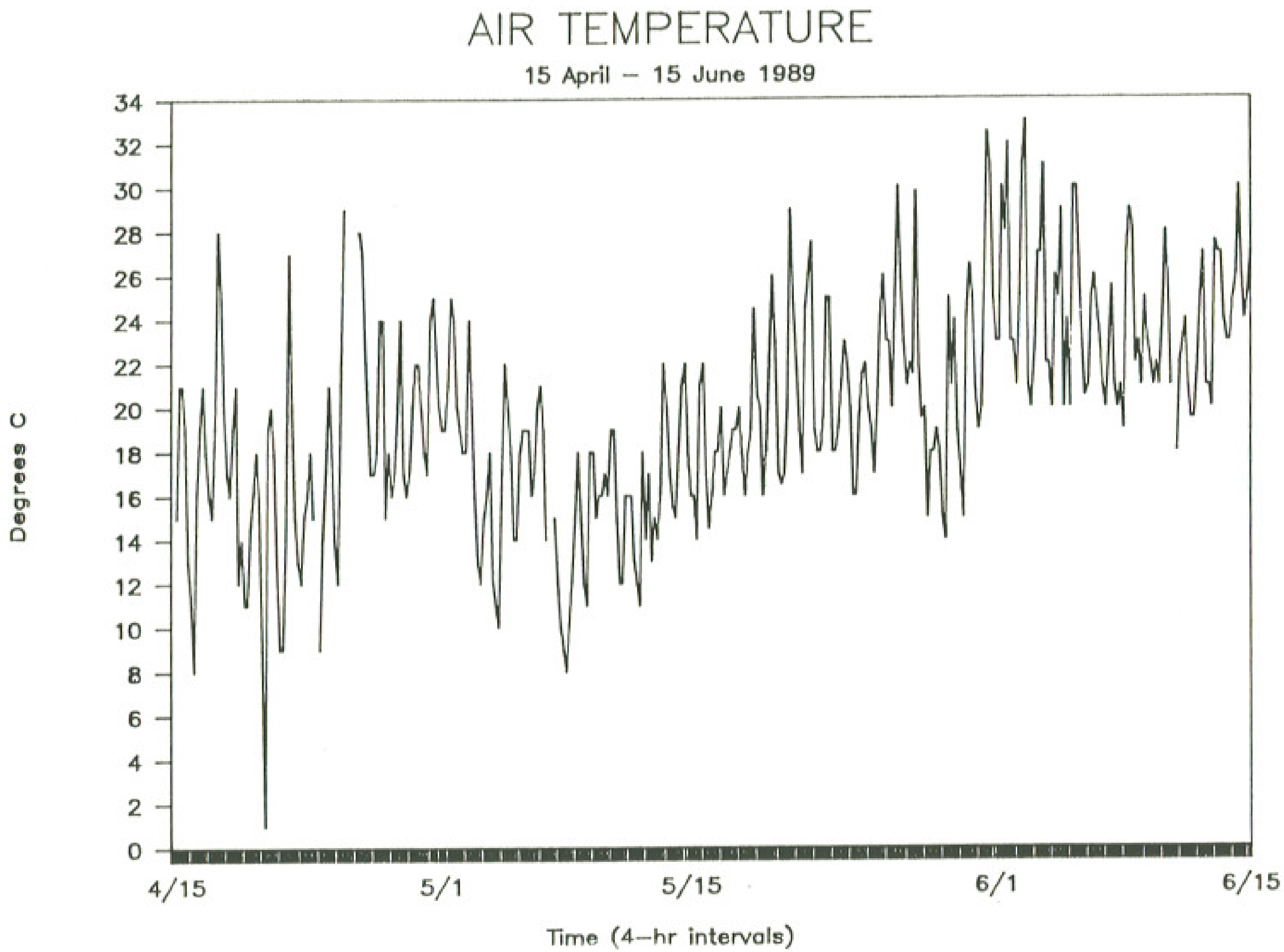
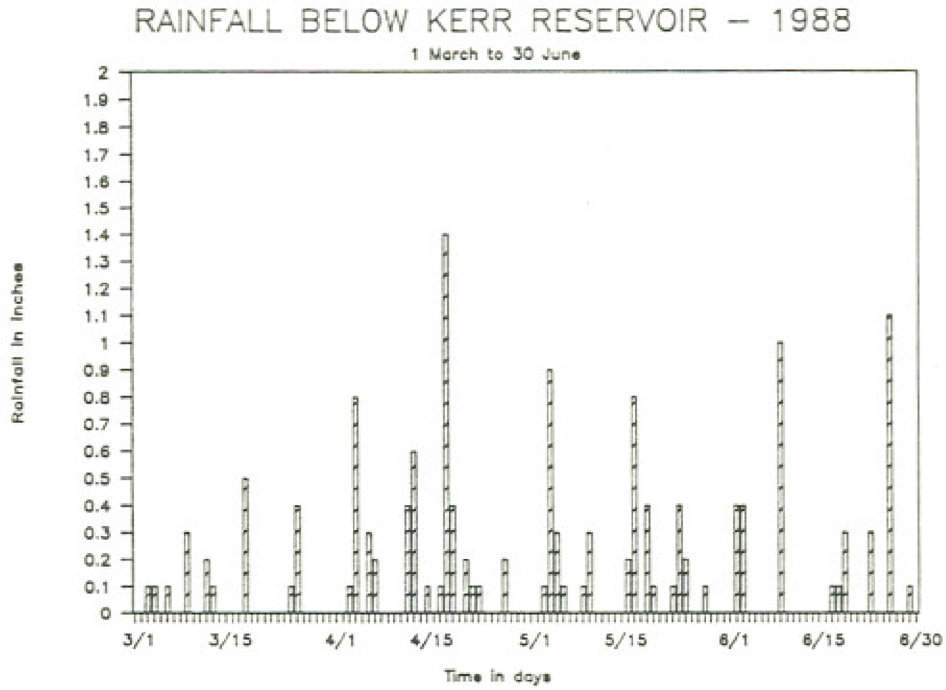


Figure 7. Air temperature (°C) measured at Barnhill's Landing, NC, for the period 15 April to 15 June 1989.



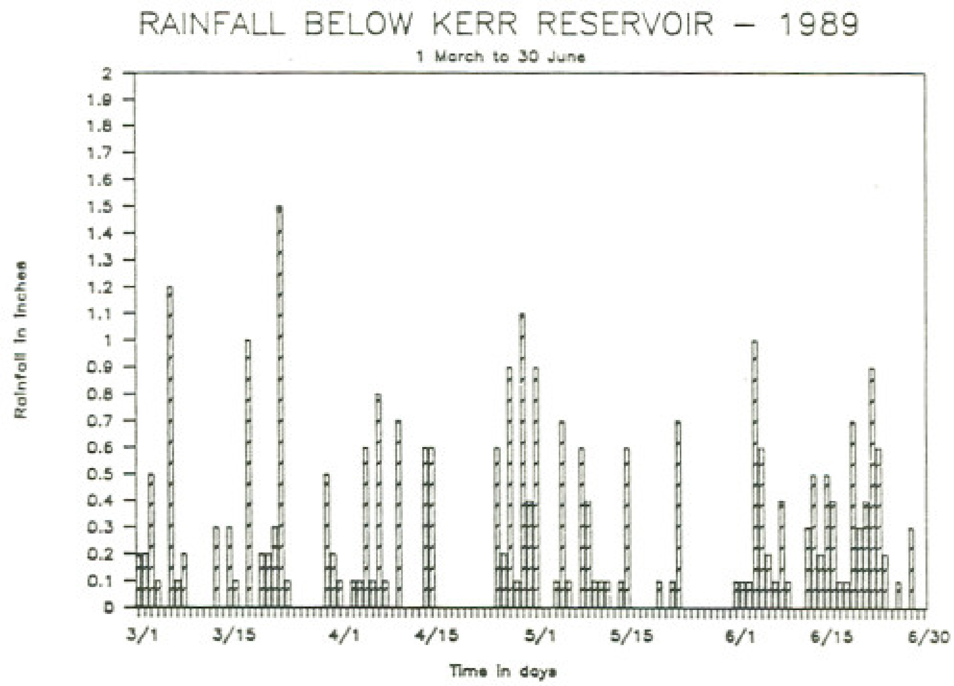


Figure 8. Daily rainfall (inches) in the Roanoke watershed below Kerr Reservoir, March through June 1988 and 1989 (U.S. Army Corps of Engineers data).

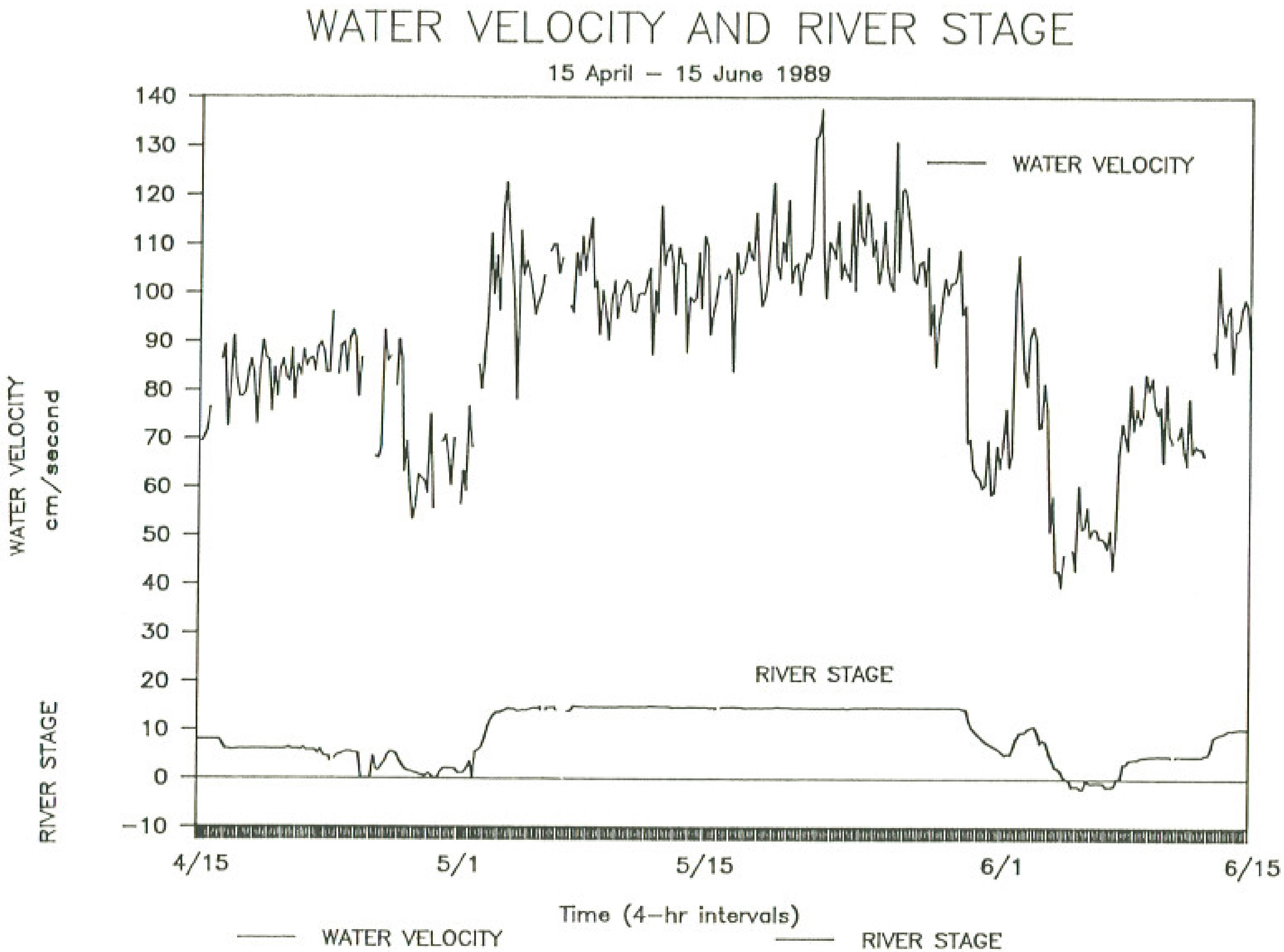


Figure 9. Surface water velocity and relative change in river stage of the Roanoke River at Barnhill's Landing, NC, for the period 15 April to 15 June 1989.

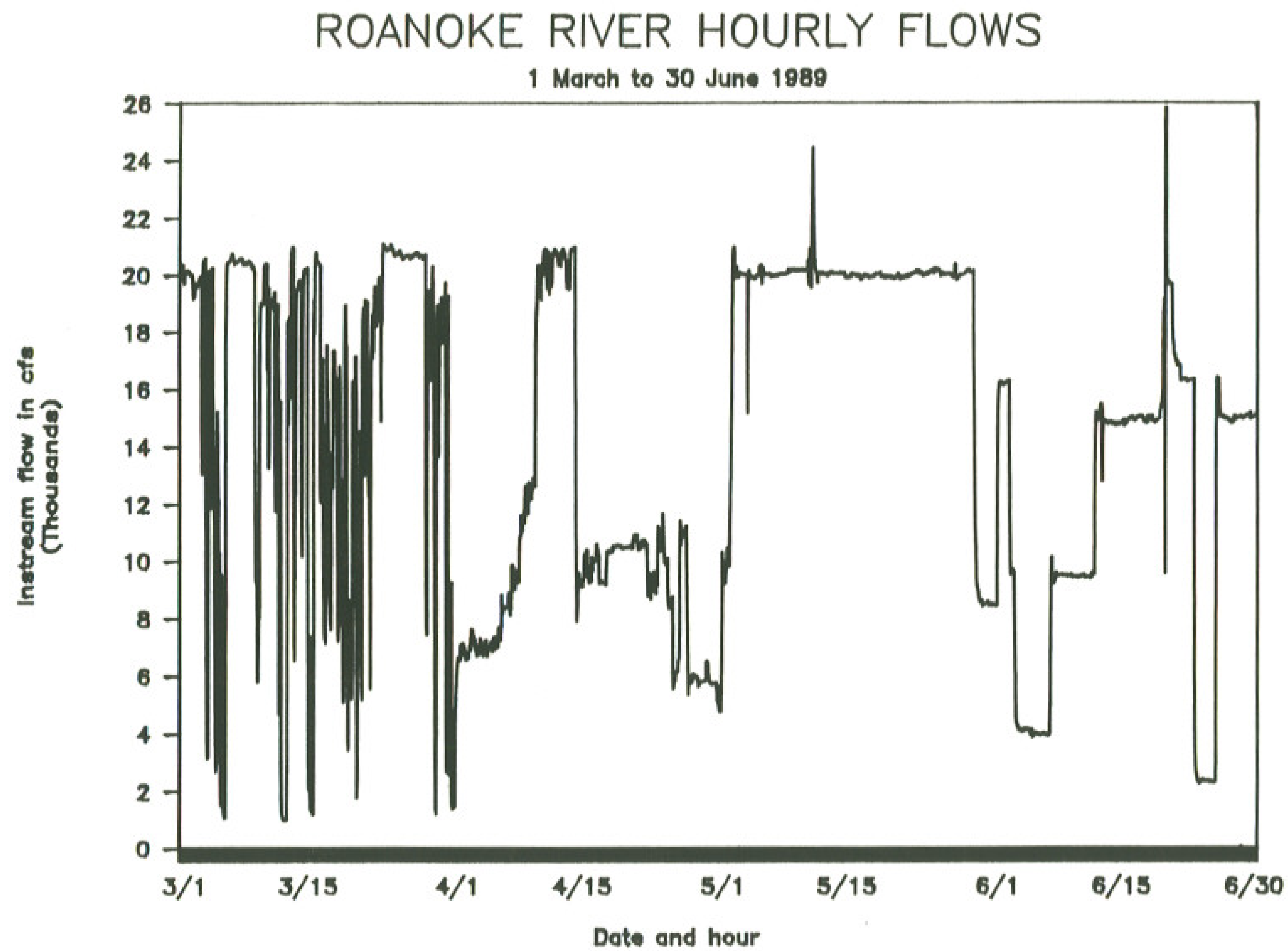


Figure 10. Hourly record of Roanoke River flows (cfs) downstream of the Roanoke Rapids Reservoir (USGS data), March through June 1989.

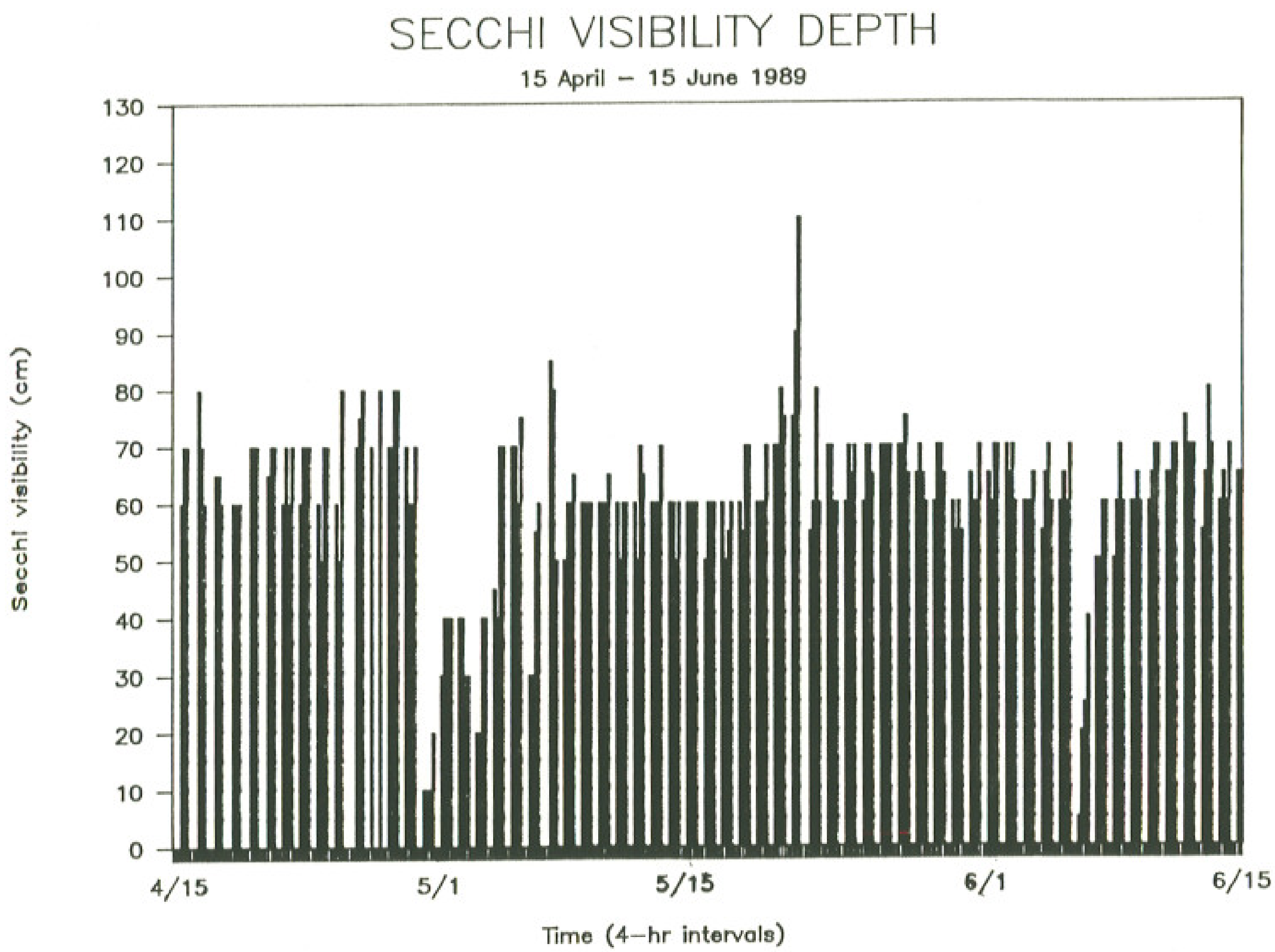


Figure 11. Depth (cm) of secchi disk visibility in the Roanoke River at Barnhill's Landing, NC, for the period 15 April to 15 June 1989. Unfilled bars indicate no information available.

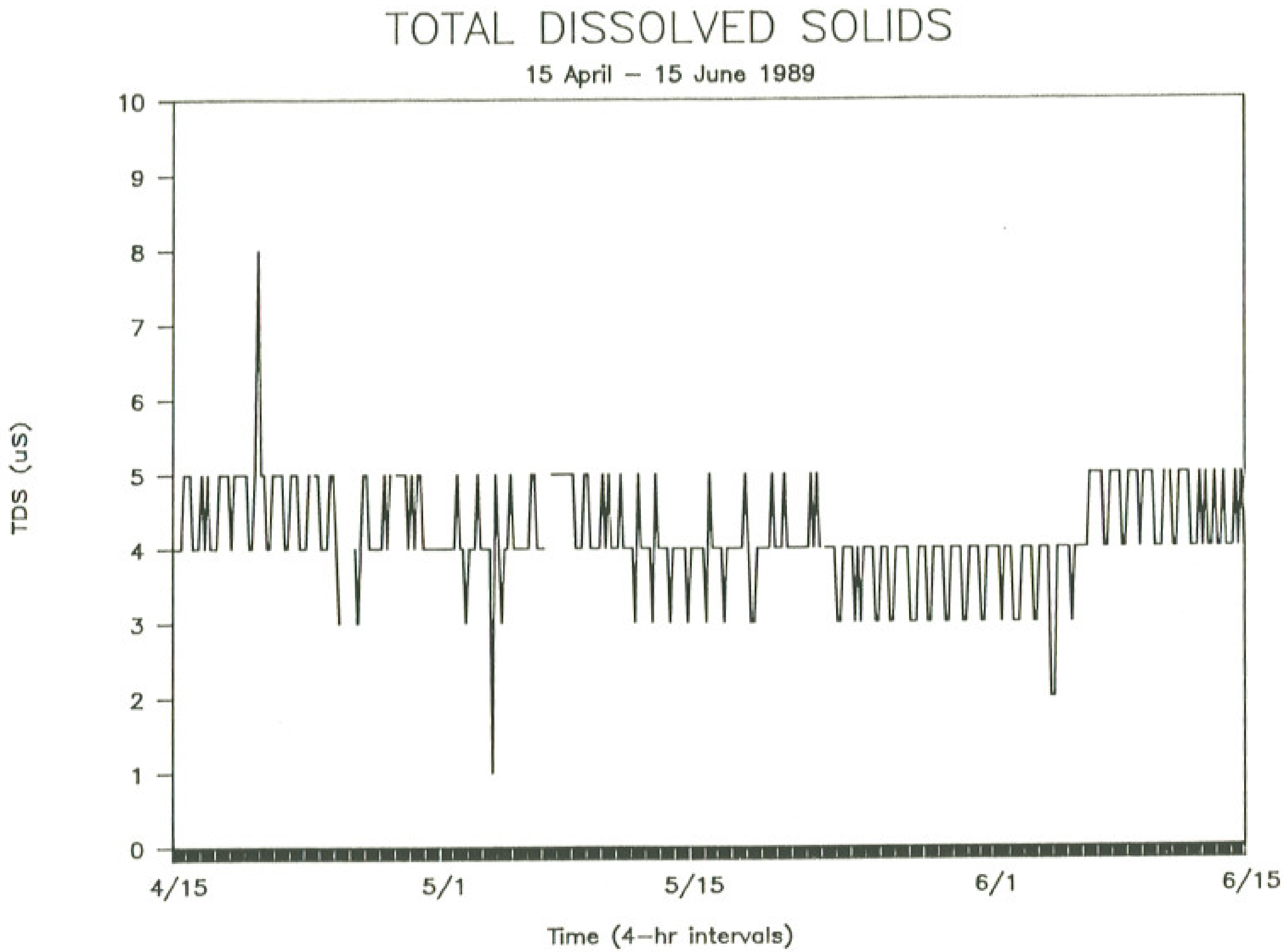


Figure 12. Levels of total dissolved solids (µS) measured in the Roanoke River at Barnhill's Landing, NC, for the period 15 April to 15 June 1989.

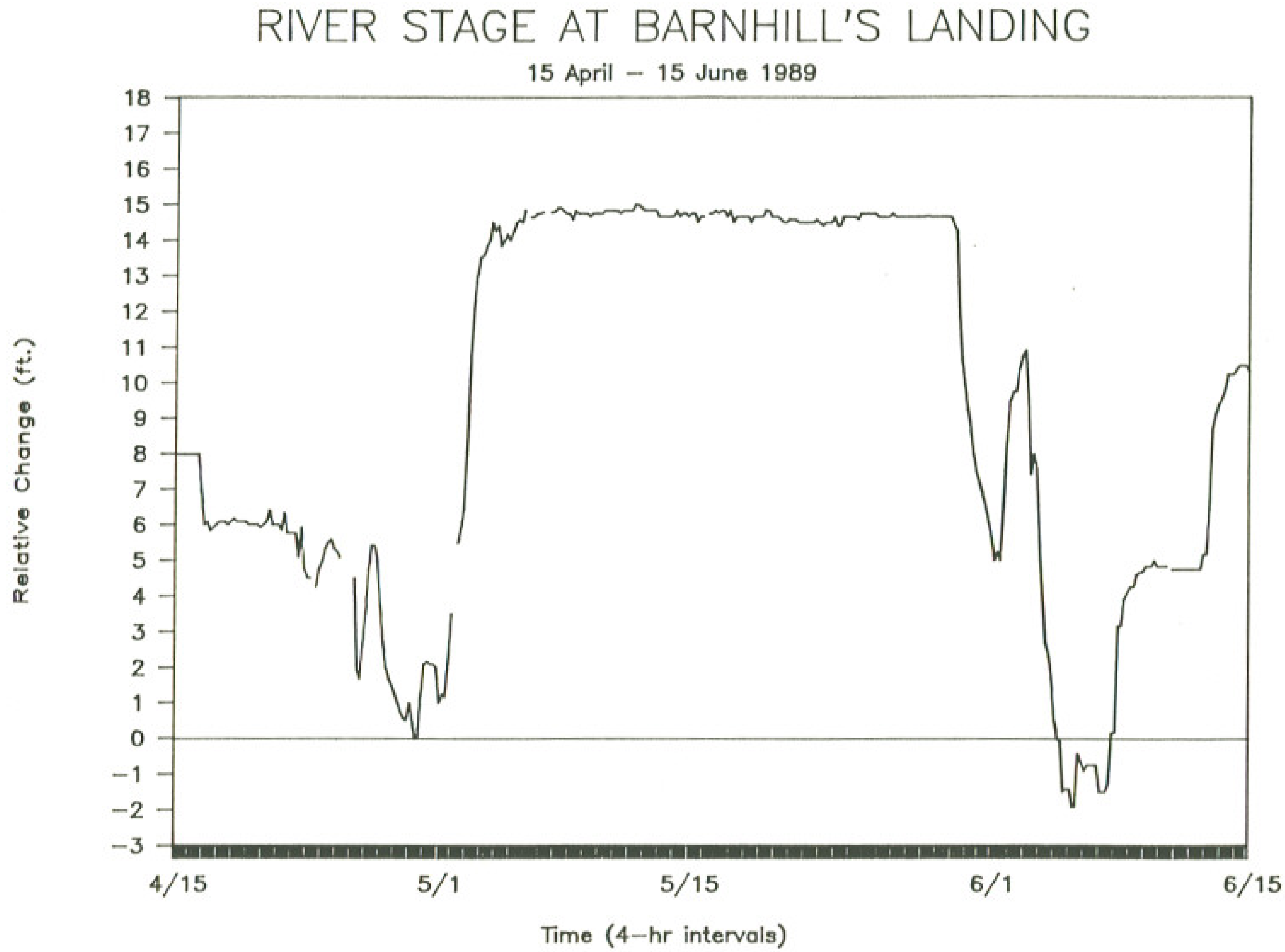


Figure 13. Relative change in stage of the Roanoke River at Barnhill's Landing, NC, for the period 15 April to 15 June 1989.

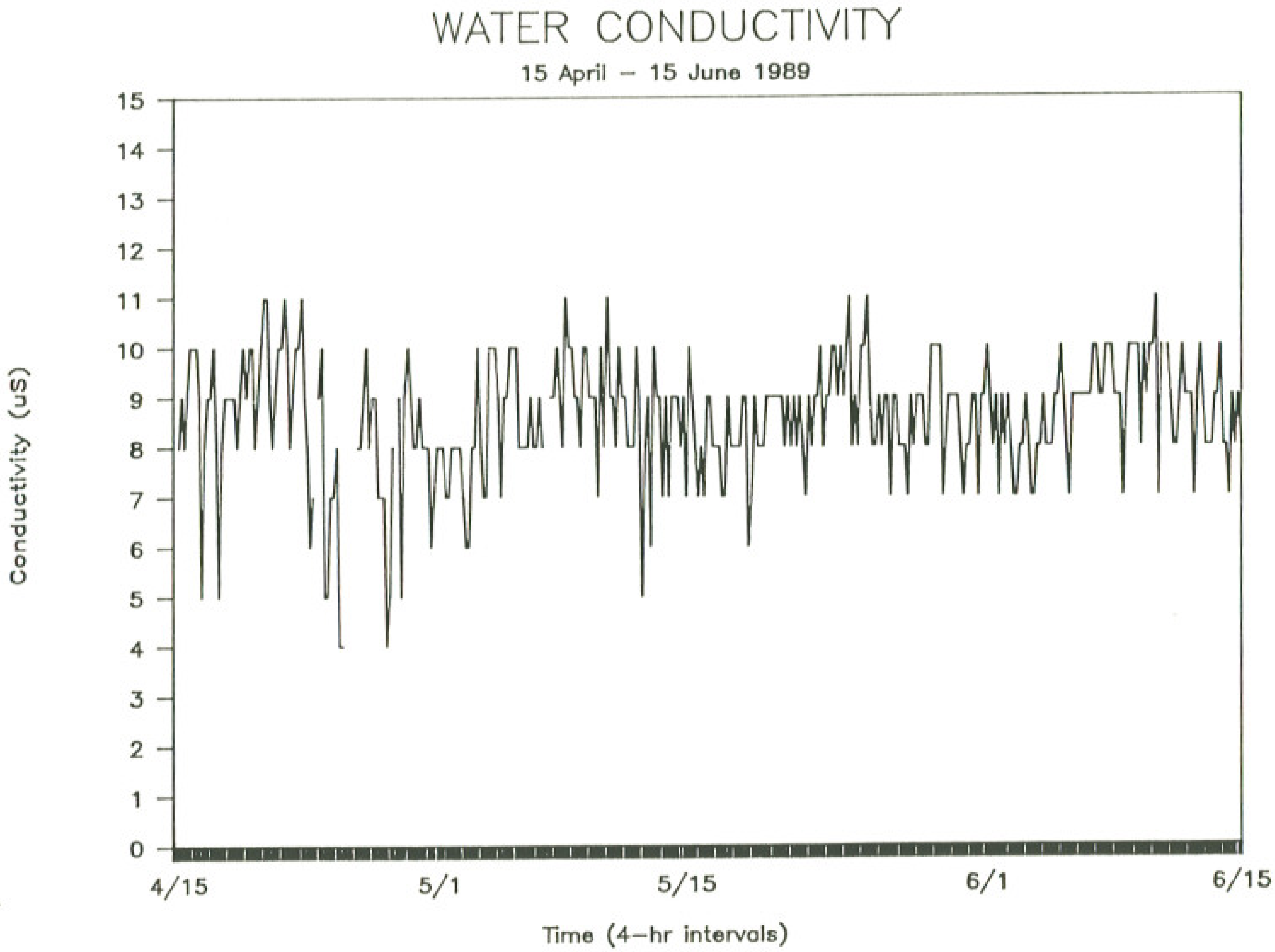


Figure 14. Changes in conductivity of Roanoke River waters at Barnhill's Landing, NC, for the period 15 April to 15 June 1989.

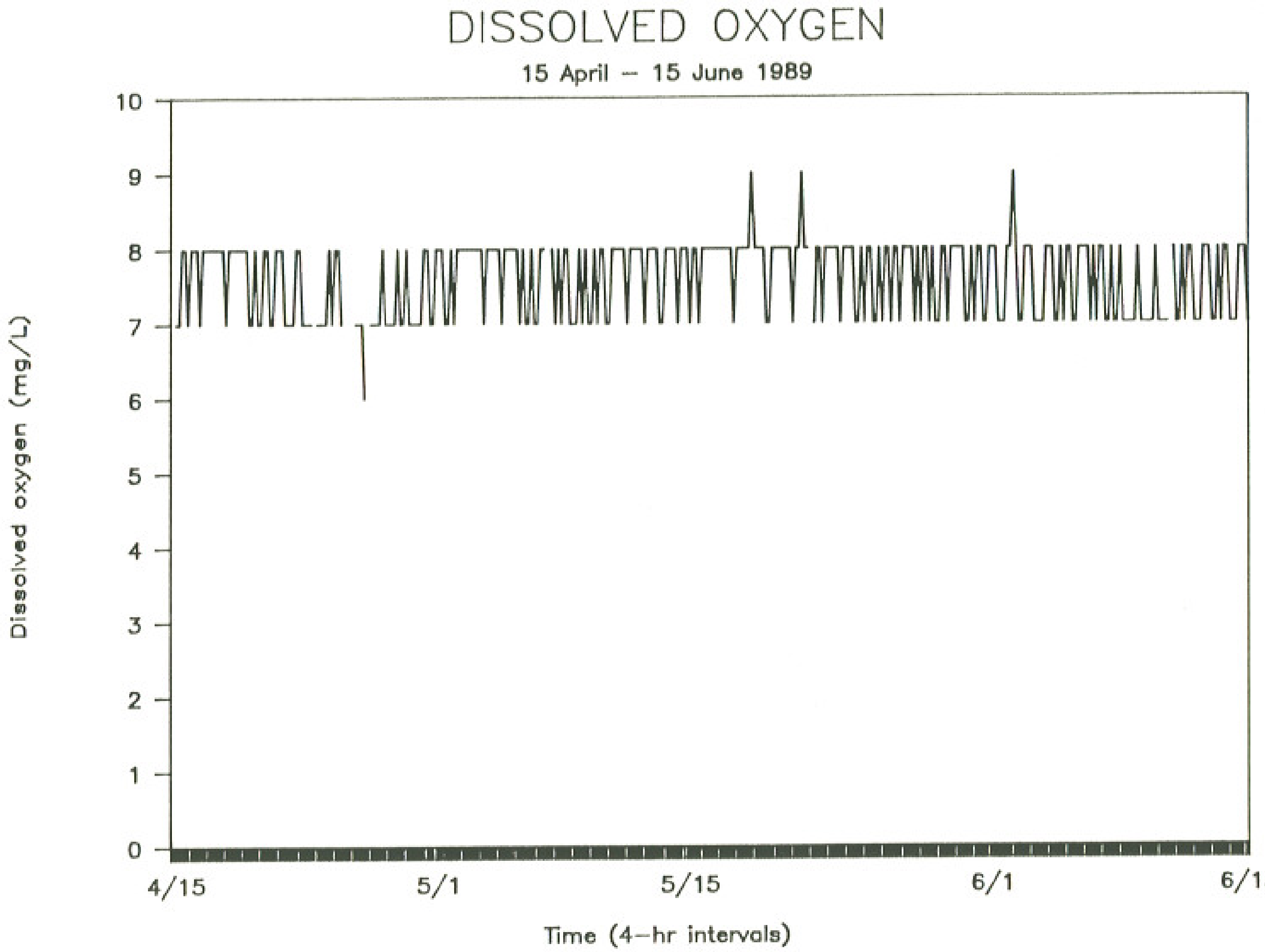


Figure 15. Changes in dissolved oxygen (mg/L) of Roanoke River waters at Barnhill's Landing, NC, for the period 15 April to 15 June 1989.

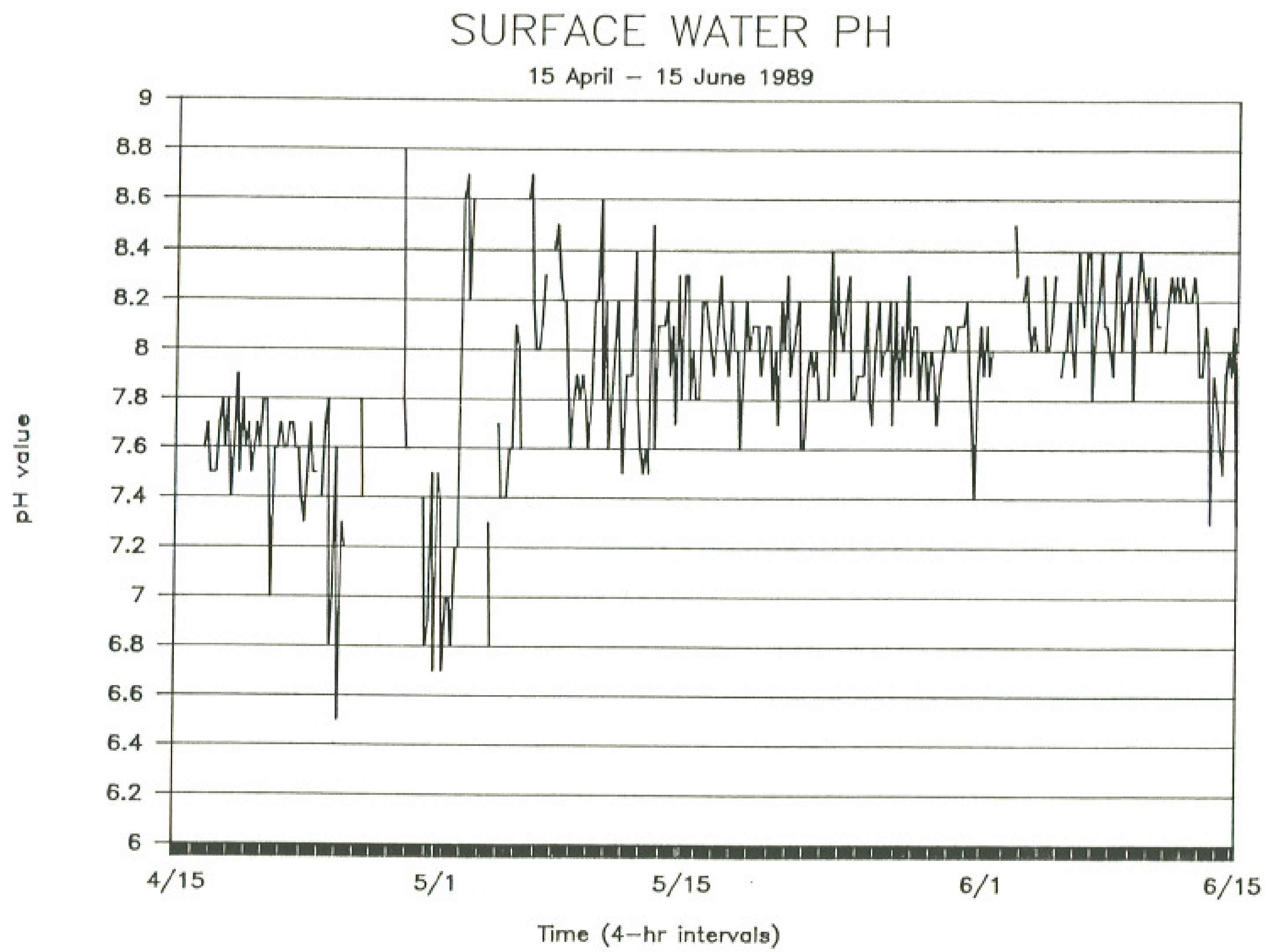


Figure 16. Changes in pH of Roanoke River waters at Barnhill's Landing, NC, for the period 15 April to 15 June 1989.

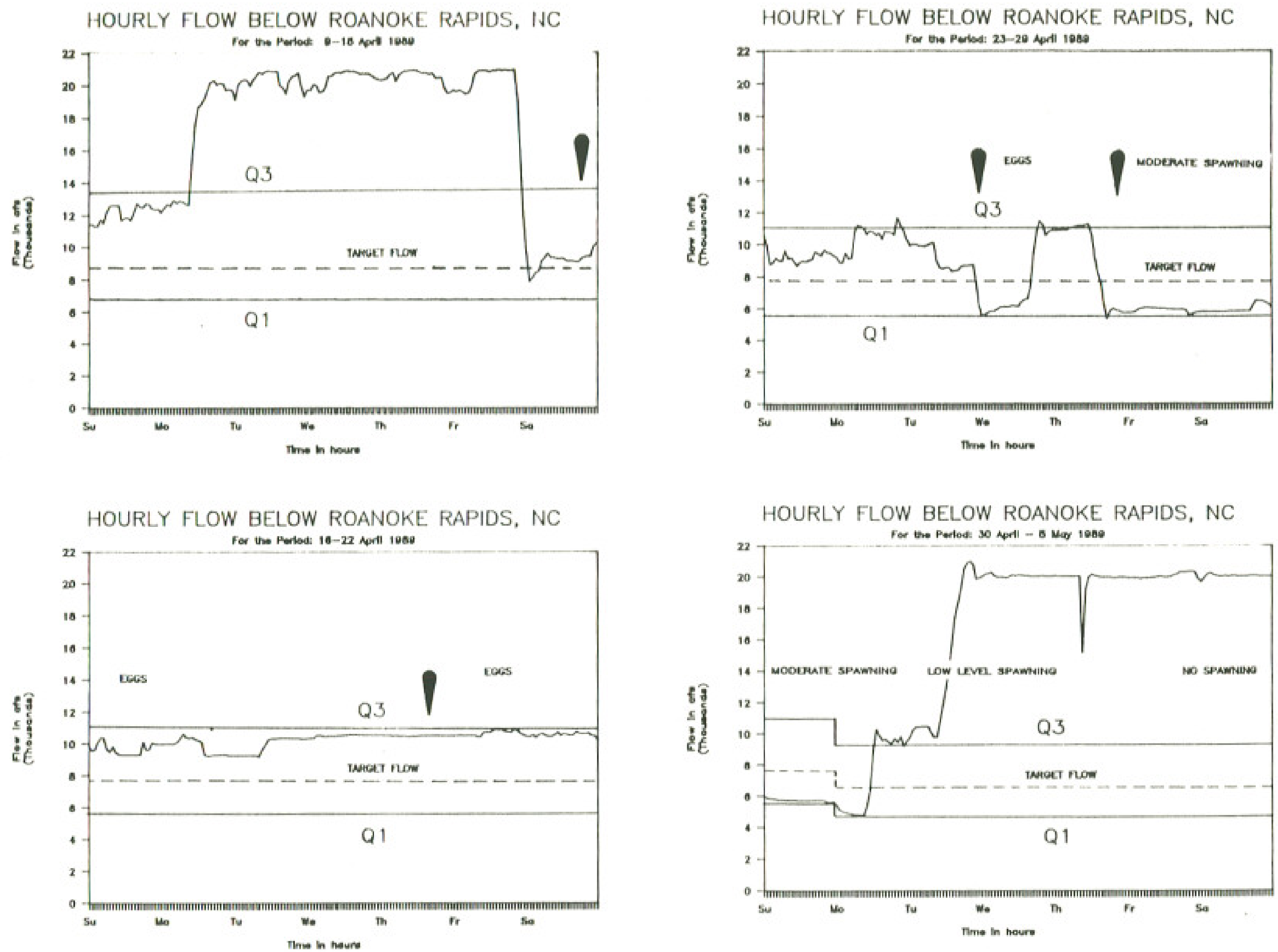
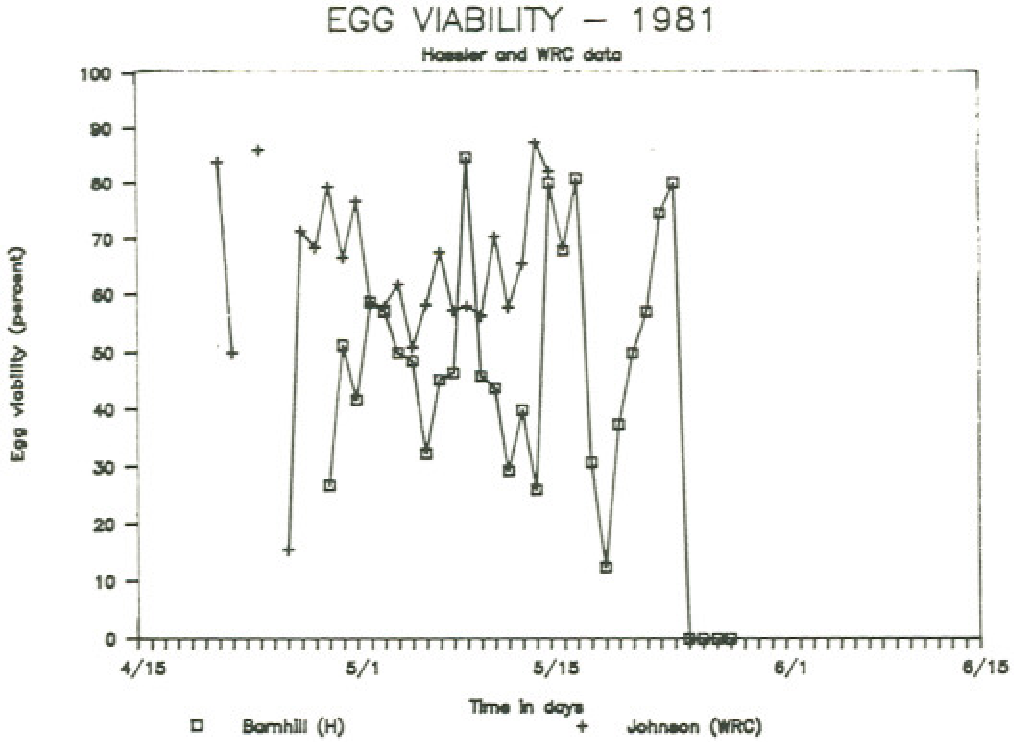


Figure 17. Roanoke River flow and spawning activity of striped bass for the period 9 April to 5 May 1989. Q1 = historical 25% low flows; Q3 = historical 75% high flows; Target flow = Negotiated Flow Regime accepted by the Army Corps of Engineers and Virginia Power Company (Manooch and Rulifson 1989).



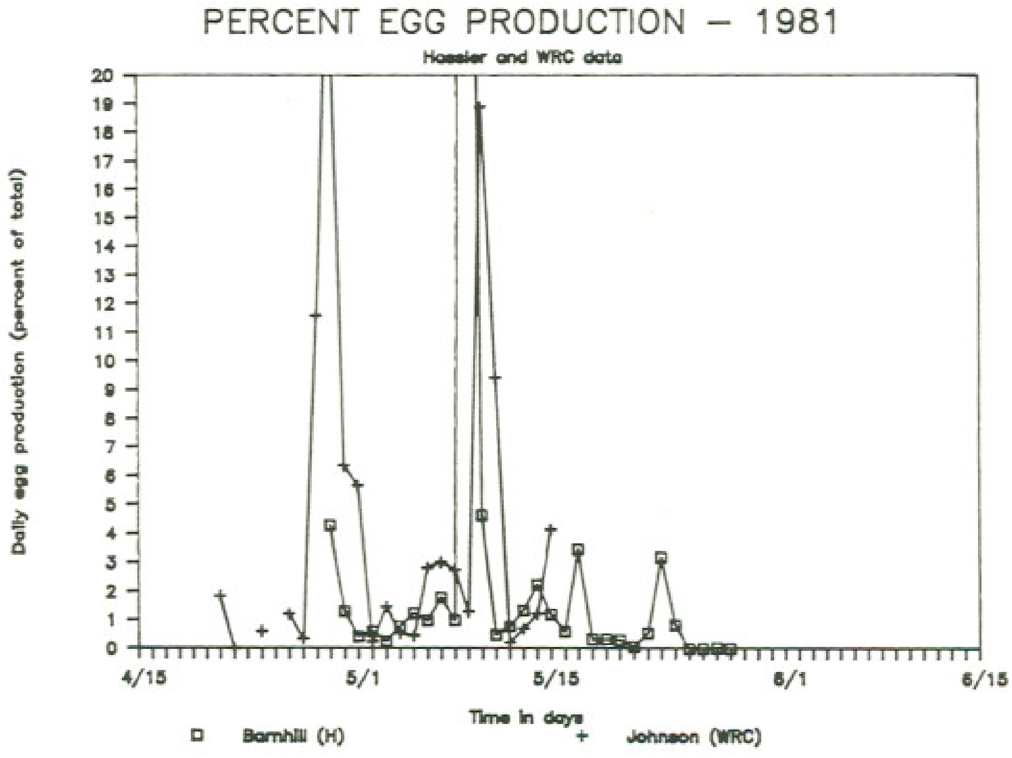


Figure 18. Daily estimates of striped bass egg production and viability in the Roanoke River by Hassler (Barnhill's Landing) and the Wildlife Resources Commission (Johnson's Landing) for the 1981 spawning season.

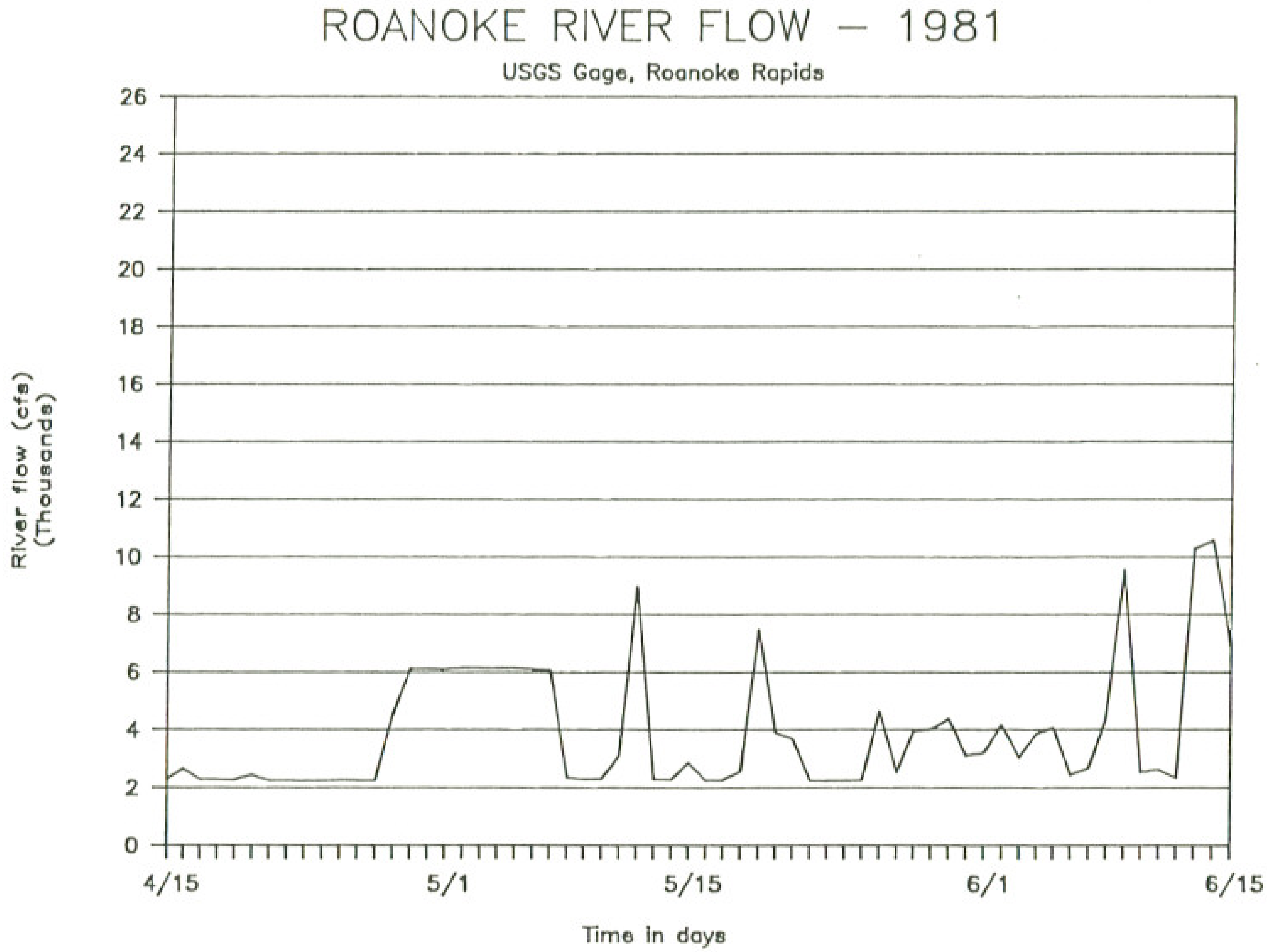
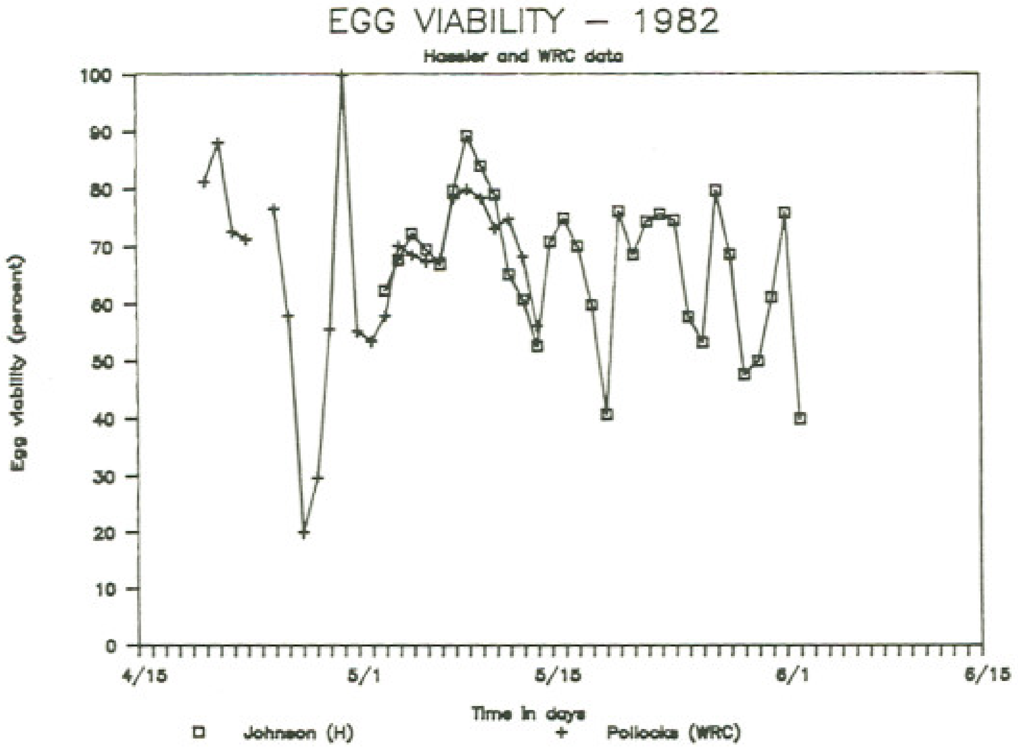


Figure 19. Average daily flow (cfs) of the Roanoke River for the period 15 April to 15 June 1981 (USGS data).



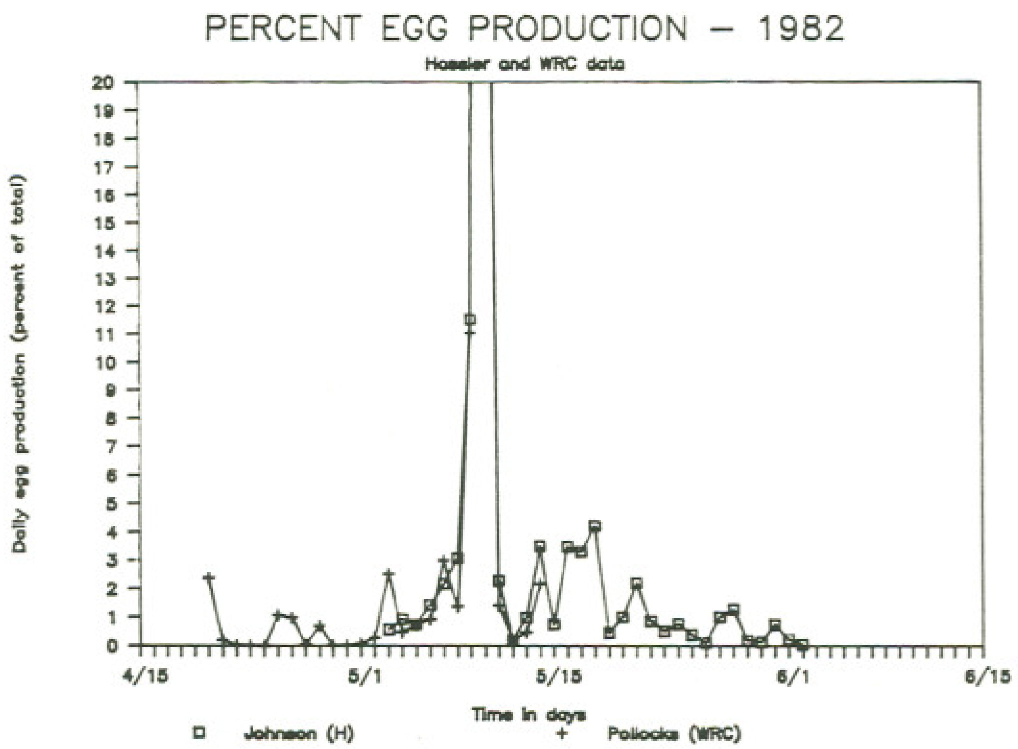


Figure 20. Daily estimates of striped bass egg production and viability in the Roanoke River by Hassler (Johnson's Landing) and the Wildlife Resources Commission (Pollock's Ferry) for the 1982 spawning season.

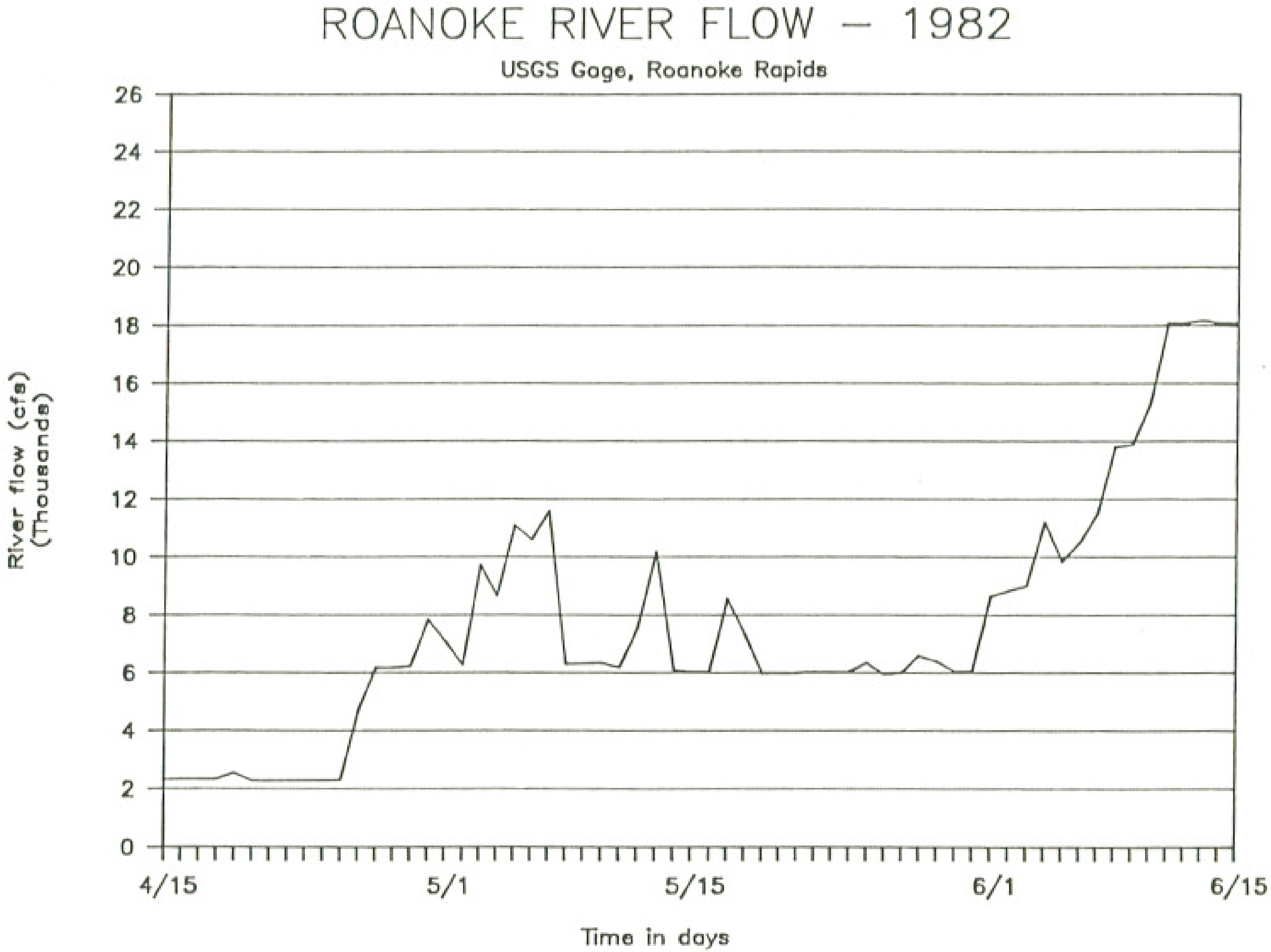


Figure 21. Average daily flow (cfs) of the Roanoke River for the period 15 April to 15 June 1982 (USGS data).

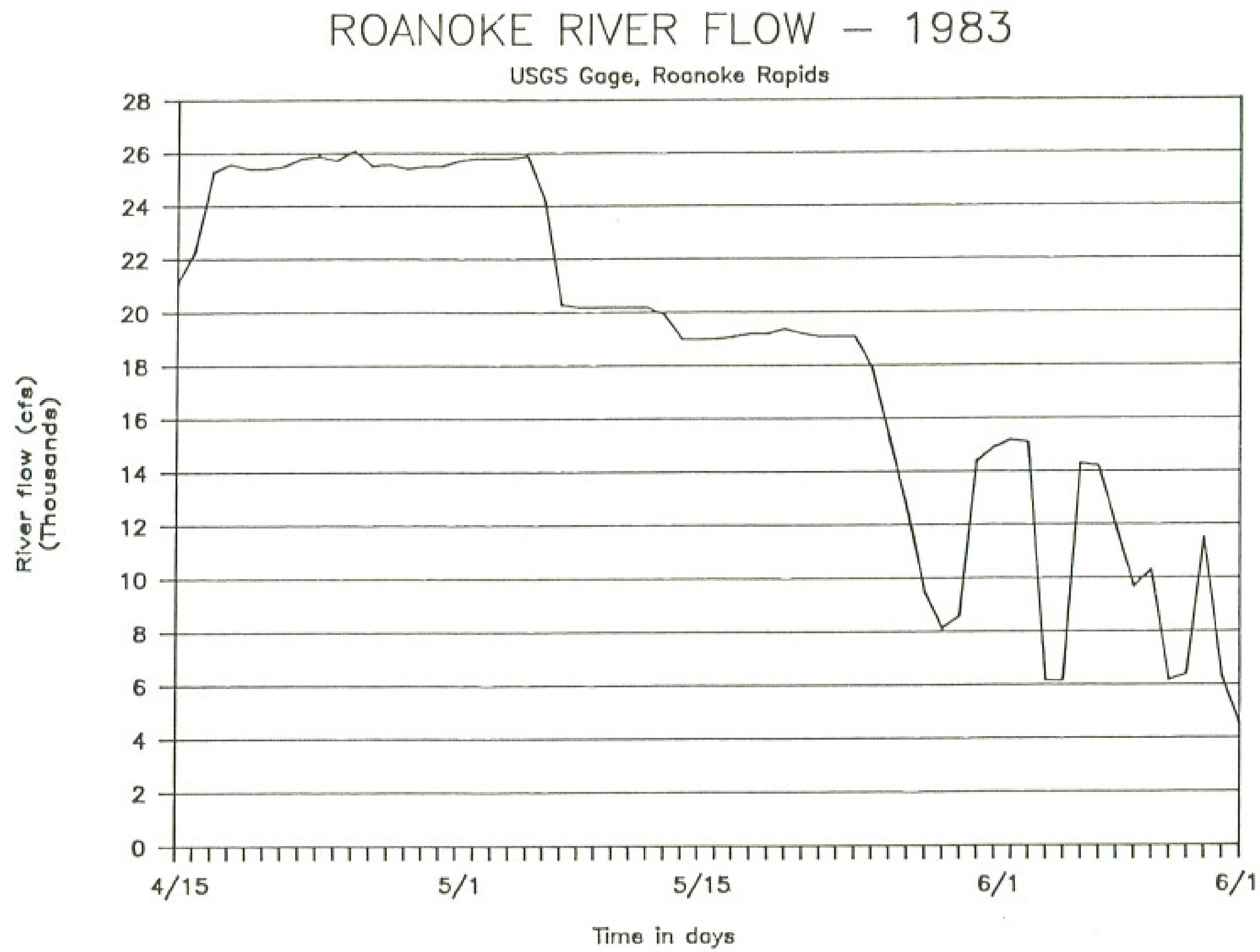
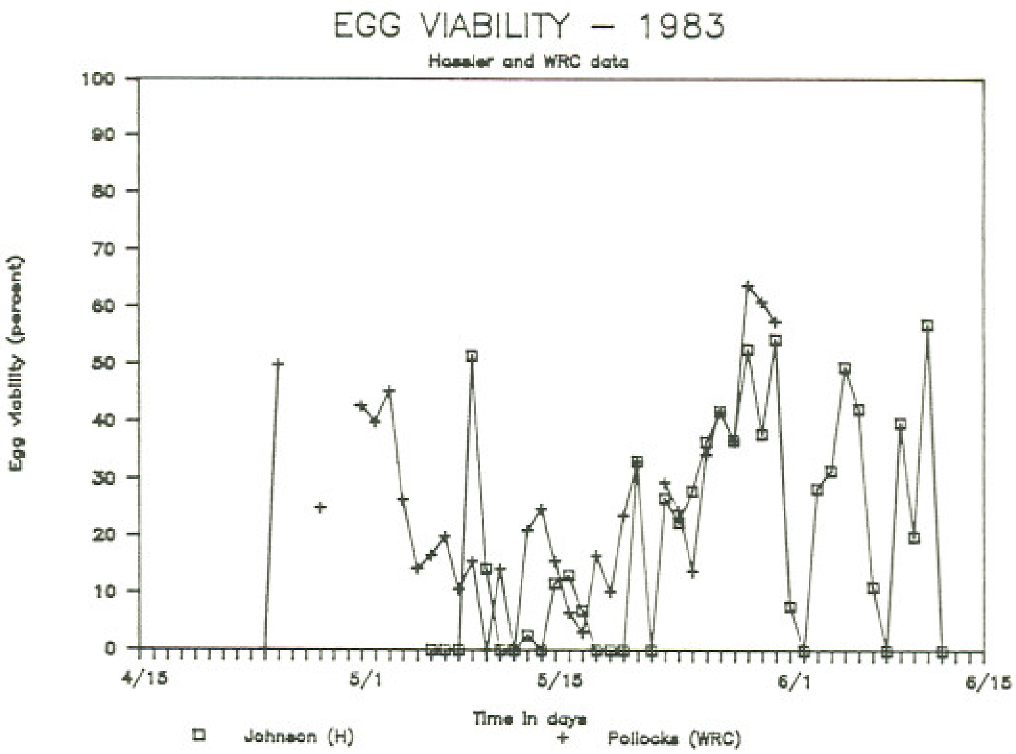


Figure 22. Average daily flow (cfs) of the Roanoke River for the period 15 April to 15 June 1983 (USGS data).



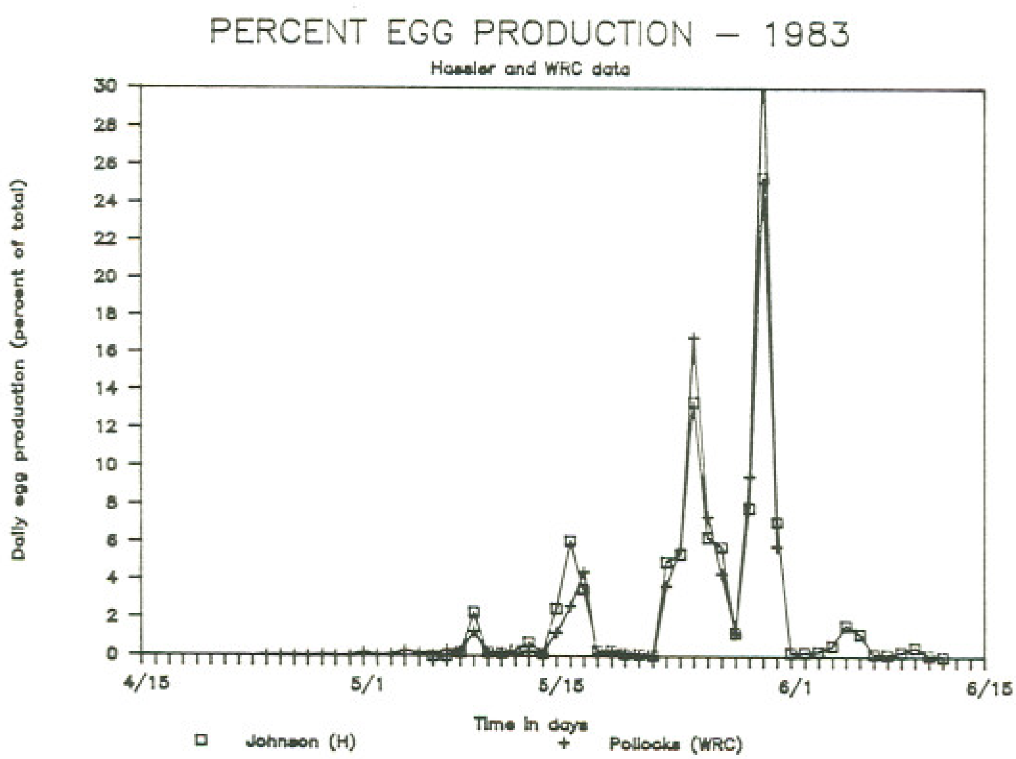


Figure 23. Daily estimates of striped bass egg production and viability in the Roanoke River by Hassler (Johnson's Landing) and the Wildlife Resources Commission (Pollock's Ferry) for the 1983 spawning season.

Table 1. Striped bass spawning in the Roanoke River, NC, as estimated from samples collected in surface waters at Barnhill's Landing, 1989.

Date	Number samples	Average river stage (ft)	Area of river cross-section (sq.ft)	Average eggs/net	Est. no. eggs/day	Percentage of total spawning	Cumulative percentage of spawning
890317	0	.	.	.	.	.	.
890323	0	.	.	.	.	.	.
890329	0	.	.	.	.	.	.
890406	2	.	.	0.00	.	.	0.00
890412	2	.	.	0.00	.	.	0.00
890414	0	.	.	.	.	.	.
890415	0	.	.	.	.	.	.
890416	8	8.0	2,445	0.13	157,193	0.02	0.02
890417	12	7.5	2,366	0.00	0	0.00	0.02
890418	12	6.0	2,128	0.00	0	0.00	0.02
890419	10	6.1	2,140	0.00	0	0.00	0.02
890420	12	6.0	2,133	0.00	0	0.00	0.02
890421	12	6.1	2,138	0.00	0	0.00	0.02
890422	12	5.9	2,115	0.00	0	0.00	0.02
890423	12	5.1	1,988	0.00	0	0.00	0.02
890424	10	5.0	1,969	0.00	0	0.00	0.02
890425	8	5.3	2,022	0.00	0	0.00	0.02
890426	8	2.7	1,625	0.00	0	0.00	0.02
890427	10	4.6	1,919	0.00	0	0.00	0.02
890428	12	1.7	1,487	2.58	1,975,890	0.31	0.33
890429	10	0.7	1,346	1.30	899,597	0.14	0.48
890430	10	1.9	1,518	6.80	5,307,658	0.83	1.31
890501	10	1.8	1,507	9.60	7,440,172	1.17	2.47
890502	10	7.4	2,349	6.00	7,249,576	1.14	3.61
890503	12	13.3	3,346	0.00	0	0.00	3.61
890504	12	14.2	3,510	0.58	1,053,124	0.17	3.78
890505	12	14.4	3,562	0.25	457,930	0.07	3.85
890506	10	14.2	3,513	0.00	0	0.00	3.85
890507	8	14.3	3,543	0.00	0	0.00	3.85
890508	12	14.8	3,627	0.00	0	0.00	3.85
890509	12	14.8	3,631	0.00	0	0.00	3.85
890510	12	14.8	3,634	0.00	0	0.00	3.85
890511	12	14.8	3,634	0.25	467,258	0.07	3.92
890512	12	14.9	3,652	0.00	0	0.00	3.92
890513	12	14.7	3,620	0.00	0	0.00	3.92
890514	12	14.7	3,624	0.00	0	0.00	3.92
890515	12	14.7	3,613	0.08	154,858	0.02	3.94
890516	10	14.8	3,634	0.00	0	0.00	3.94
890517	12	14.7	3,613	0.00	0	0.00	3.94
890518	12	14.7	3,606	0.33	618,239	0.10	4.04
890519	12	14.7	3,620	1.42	2,637,645	0.41	4.45
890520	12	14.6	3,589	3.00	5,537,258	0.87	5.32
890521	12	14.5	3,575	6.92	12,717,366	1.99	7.32
890522	12	14.5	3,572	15.25	28,012,436	4.39	11.71
890523	12	14.6	3,586	52.50	96,812,007	15.18	26.88
890524	12	14.7	3,617	40.58	75,487,716	11.83	38.72
890525	12	14.8	3,627	6.58	12,280,878	1.93	40.64

Table 1. *continued*

Date	Number samples	Average river stage (ft)	Area of river cross-section (sq.ft)	Average eggs/net	Est. no. eggs/day	Percentage of total spawning	Cumulative percentage of spawning
890526	12	14.7	3,617	28.75	53,477,171	8.38	49.03
890527	12	14.7	3,613	86.92	161,515,856	25.32	74.34
890528	12	14.7	3,613	14.33	26,635,405	4.18	78.52
890529	12	14.7	3,613	6.42	11,923,989	1.87	80.39
890530	12	11.8	3,083	6.75	10,701,231	1.68	82.07
890531	12	7.4	2,358	62.17	75,377,001	11.82	93.88
890601	12	5.6	2,065	25.92	27,529,283	4.32	98.20
890602	12	9.8	2,732	3.67	5,150,997	0.81	99.01
890603	12	8.1	2,469	0.67	846,596	0.13	99.14
890604	10	1.9	1,514	2.10	1,635,242	0.26	99.39
890605	12	-1.4	1,075	1.83	1,013,250	0.16	99.55
890606	12	-0.7	1,158	1.67	992,237	0.16	99.71
890607	12	-1.1	1,114	1.25	716,138	0.11	99.82
890608	12	3.1	1,696	0.83	726,977	0.11	99.94
890609	12	4.6	1,918	0.42	410,989	0.06	100.00
890610	12	4.8	1,946	0.00	0	0.00	100.00
890611	10	4.8	1,941	0.00	0	0.00	100.00
890612	10	4.9	1,951	0.00	0	0.00	100.00
890613	10	8.1	2,463	0.00	0	0.00	100.00
890614	12	10.3	2,813	0.00	0	0.00	100.00
890615	6	10.4	2,840	0.00	0	0.00	100.00

Table 2. Estimated number of striped bass eggs spawned in the Roanoke River, NC, 1959-1987 (Hassler and co-workers, 1959-1987), 1988 (Rulifson 1989), and 1989 (this study). Egg production and viability data from 1959 through 1987 taken from Hassler and Maraveyias (1987).

Year	Sampling Period	Number of eggs	Egg viability (%)	Site of egg collection
1959	8 May-23 May[1]	300,000,000	92.88	Palmyra (RM 78.5)
1960	23 Apr-8 Jun[1]	740,000,000	92.88	Palmyra
1961	29 Apr-14 Jun	2,065,232,519	79.24	Halifax (RM 121)
1962	24 Apr-5 Jun	1,088,076,294	86.22	Halifax
1963	18 Apr-8 Jun[2]	918,652,436	79.94	Halifax
1964	24 Apr-27 May	1,285,351,276	95.77	Halifax
1965	21 Apr-28 May	823,522,540	95.91	Halifax
1966	26 Apr-31 May	1,821,385,754	94.51	Halifax
1967	21 Apr-11 Jun	1,333,312,869	96.20	Halifax
1968	24 Apr-4 Jun	1,483,102,338	86.20	Halifax
1969	27 Apr-6 Jun	3,229,715,526	89.86	Halifax
1970	30 Apr-1 Jun	1,464,841,490	89.23	Halifax
1971	1 May-2 Jun	2,833,119,620	80.81	Halifax
1972	2 May-28 May	4,932,000,707	90.51	Halifax
1973	29 Apr-3 Jun	1,501,498,887	87.21	Halifax
1974	1 May-2 Jun	2,163,239,468	87.31	Halifax
1975	7 May-2 Jun	2,193,008,096	55.69	Barnhill's (RM 117)
1976	1 May-30 May	1,496,768,659	50.73	Barnhill's Landing
1977	29 Apr-31 May	1,775,957,318	52.72	Barnhill's Landing
1978	29 Apr-22 Jun	1,691,227,585	37.72	Barnhill's Landing
1979	10 May-11 Jun	1,613,382,382	43.62	Barnhill's Landing
1980	1 May-1 Jun	870,322,832	43.39	Barnhill's Landing
1981	29 Apr-29 May	344,364,065	73.70	Barnhill's Landing
1982	3 May-2 Jun	1,698,888,853	71.93	Johnson's (RM 118)
1983	6 May-12 Jun	1,352,611,202	33.29	Johnson's Landing
1984	9 May-9 Jun	703,879,559	22.73	Johnson's Landing
1985	23 Apr-23 May	600,562,645	72.21	Johnson's Landing
1986	28 Apr-31 May	2,279,071,483	51.10	Johnson's Landing
1987	27 Apr-9 Jun	1,382,496,006	42.87	Johnson's Landing
1988	10 Apr-7 Jun	2,082,130,728	89.00	Pollock's Ferry (RM 105)
1989	16 Apr-15 Jun	637,919,162	41.80	Barnhill's Landing

[1] Incomplete sampling season; estimates are partial.
[2] Spawning season interrupted from 21 April to 1 May because of an extensive fish kill just after a 10-day minimum flow period (Hassler et al. 1963).

Table 3. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1989.

Date	Number samples	Number non-viable eggs	Number viable eggs	Percentage viable eggs
890317	0	.	.	.
890323	0	.	.	.
890329	0	.	.	.
890406	2	0	0	.
890412	2	0	0	.
890414	0	.	.	.
890415	0	.	.	.
890416	8	1	0	0.00
890417	12	0	0	.
890418	12	0	0	.
890419	10	0	0	.
890420	12	0	0	.
890421	12	0	0	.
890422	12	0	0	.
890423	12	0	0	.
890424	10	0	0	.
890425	8	0	0	.
890426	8	0	0	.
890427	10	0	0	.
890428	12	23	8	25.81
890429	10	7	6	46.15
890430	10	22	46	67.65
890501	10	31	65	67.71
890502	10	30	30	50.00
890503	12	0	0	.
890504	12	4	3	43.86
890505	12	2	1	33.33
890506	10	0	0	.
890507	8	0	0	.
890508	12	0	0	.
890509	12	0	0	.
890510	12	0	0	.
890511	12	0	3	100.00
890512	12	0	0	.
890513	12	0	0	.
890514	12	0	0	.
890515	12	1	0	0.00
890516	10	0	0	.
890517	12	0	0	.
890518	12	3	1	25.00
890519	12	9	8	47.06
890520	12	18	18	50.00
890521	12	60	23	27.71
890522	12	115	68	37.16
890523	12	335	295	46.83
890524	12	210	277	56.88
890525	12	50	29	36.71
890526	12	213	132	38.26

Table 3. *continued*

Date	Number samples	Number non-viable eggs	Number viable eggs	Percentage viable eggs
890527	12	742	301	28.86
890528	12	117	55	31.98
890531	12	410	336	45.04
890601	12	179	132	42.44
890602	12	35	9	20.45
890603	12	8	0	0.00
890604	10	7	14	66.67
890605	12	8	14	63.64
890606	12	12	8	40.00
890607	12	4	11	73.33
890608	12	5	5	50.00
890609	12	1	4	80.00
890610	12	0	0	.
890611	10	0	0	.
890612	10	0	0	.
890613	10	0	0	.
890614	12	0	0	.
890615	6	0	0	.

Table 4. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1989, as a function of temperature.

Temperature range (°C)	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
14.0-15.9	1	1	50.00	0.042
16.0-17.9	82	62	43.06	3.050
18.0-19.9	1,006	900	47.22	40.364
20.0-21.9	1,451	829	36.36	48.285
22.0-23.9	208	176	45.83	8.132
24.0-25.9	0	6	0.00	0.127
Totals	2,748	1,974		100.000

Table 5. Striped bass egg viability in surface waters of the Roanoke River at Barnhill's Landing, NC, 1989, as a function of surface water velocity.

Water velocities (cm/second)	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
missing	7	13	65.00	0.424
40.0-59.9	157	171	52.13	6.946
60.0-79.9	569	452	44.27	21.622
80.0-99.9	235	167	41.54	8.513
100.0-119.9	1,603	1,116	41.04	57.582
120.0-139.9	177	55	23.71	4.913
	2,748	1,974		100.000

Table 6. Striped bass egg viability at Barnhill's Landing, Roanoke River, NC, 1989, as a function of time of day.

Time of collection	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
0200	530	322	37.79	18.043
0600	753	581	43.55	28.251
1000	624	409	39.59	21.876
1400	307	201	39.57	10.758
1800	171	127	42.62	6.311
2200	363	334	47.92	14.761
	2,748	1,974		100.000

Table 7. Striped bass egg viability in surface waters of the Roanoke River at Barnhill's Landing, NC, 1989, as a function of dissolved oxygen (mg/L).

Dissolved oxygen values	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
missing	1	1	50.00	0.042
6.0-6.9	0	0	0.00	0.000
7.0-7.9	674	636	48.55	27.742
8.0-8.9	2,059	1,331	39.26	71.792
9.0-9.9	14	6	30.00	0.424
	2,748	1,974		100.000

Table 8. Striped bass egg viability in surface waters of the Roanoke River at Barnhill's Landing, North Carolina, 1989, as a function of pH.

Range of pH values	Number non-viable eggs	Number viable eggs	Percent viable eggs	Percent of all eggs collected
missing	78	65	45.45	3.028
6.50-6.74	12	15	55.56	0.572
6.75-6.99	23	35	60.34	1.228
7.00-7.24	16	49	75.38	1.377
7.25-7.49	105	60	36.36	3.494
7.50-7.74	137	124	47.51	5.527
7.75-7.99	1,137	639	35.98	37.611
8.0 or more	1,240	987	44.32	47.162
	2,748	1,974		100.000

Table 9. Raw data and egg production estimates by trip for striped bass at Barnhill's Landing, Roanoke River, North Carolina, in 1989. Combined production is the average of all samples.

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890317	1437	.	.	.	.	.	.	.	.	.
890323	1030	.	.	.	.	.	.	.	.	.
890329	1043	.	.	.	.	.	.	.	.	.
890406	1042	0	0	0	0	.	.	.	.	.
890412	1035	0	0	0	0	.	.	.	.	.
890414	1800	.	.	.	.	.	.	.	.	.
	2200	.	.	.	.	.	.	.	.	.
890415	600	.	.	.	.	.	.	.	.	.
	1000	.	.	.	.	.	.	.	.	.
	1800	.	.	.	.	.	.	.	.	.
890416	1000	0	0	0	0	8.0	2,445	0	0	0
	1400	0	1	0	0	8.0	2,445	2,183	0	1,092
	1800	0	0	0	0	8.0	2,445	0	0	0
	2200	0	0	0	0	8.0	2,445	0	0	0
890417	200	0	0	0	0	8.0	2,445	0	0	0
	600	0	0	0	0	8.0	2,445	0	0	0
	1000	0	0	0	0	8.0	2,445	0	0	0
	1400	0	0	0	0	8.0	2,445	0	0	0
	1800	0	0	0	0	7.0	2,286	0	0	0
	2200	0	0	0	0	6.0	2,128	0	0	0
890418	200	0	0	0	0	6.1	2,143	0	0	0
	600	0	0	0	0	5.8	2,096	0	0	0
	1000	0	0	0	0	5.9	2,112	0	0	0
	1400	0	0	0	0	6.0	2,128	0	0	0
	1800	0	0	0	0	6.1	2,143	0	0	0
	2200	0	0	0	0	6.1	2,143	0	0	0

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890419	200	0	0	0	0	6.1	2,143	0	0	0
	600	0	0	0	0	6.0	2,128	0	0	0
	1000	0	0	0	0	6.1	2,143	0	0	0
	1800	0	0	0	0	6.1	2,143	0	0	0
	2200	0	0	0	0	6.1	2,143	0	0	0
890420	200	0	0	0	0	6.1	2,143	0	0	0
	600	0	0	0	0	6.1	2,143	0	0	0
	1000	0	0	0	0	6.0	2,128	0	0	0
	1400	0	0	0	0	6.0	2,128	0	0	0
	1800	0	0	0	0	6.0	2,128	0	0	0
	2200	0	0	0	0	6.0	2,128	0	0	0
890421	200	0	0	0	0	5.9	2,112	0	0	0
	600	0	0	0	0	6.0	2,128	0	0	0
	1000	0	0	0	0	6.1	2,143	0	0	0
	1400	0	0	0	0	6.4	2,191	0	0	0
	1800	0	0	0	0	6.0	2,128	0	0	0
	2200	0	0	0	2	6.0	2,128	0	3,799	1,900
890422	200	0	0	0	0	6.0	2,128	0	0	0
	600	0	0	0	0	5.8	2,096	0	0	0
	1000	0	0	0	0	6.3	2,175	0	0	0
	1400	0	0	0	0	5.8	2,096	0	0	0
	1800	0	0	0	0	5.8	2,096	0	0	0
	2200	0	0	0	0	5.8	2,096	0	0	0
890423	200	0	0	0	0	5.8	2,096	0	0	0
	600	0	0	0	0	5.1	1,987	0	0	0
	1000	0	0	0	0	5.9	2,112	0	0	0
	1400	0	0	0	0	4.8	1,941	0	0	0
	1800	0	0	0	0	4.5	1,895	0	0	0
	2200	0	0	0	0	4.5	1,895	0	0	0

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890424	200	.	.	.	.	.	.	.	.	.
	600	0	0	0	0	4.3	1,864	0	0	0
	1000	0	0	0	0	4.8	1,941	0	0	0
	1400	0	0	0	0	5.0	1,972	0	0	0
	1800	0	0	0	0	5.3	2,018	0	0	0
	2200	0	0	0	0	5.5	2,050	0	0	0
890425	200	0	0	0	0	5.6	2,065	0	0	0
	600	0	0	0	0	5.3	2,018	0	0	0
	1000	0	0	0	0	5.3	2,018	0	0	0
	1400	0	0	0	0	5.1	1,987	0	0	0
	1800	.	.	.	.	.	.	.	.	.
	2200	.	.	.	.	.	.	.	.	.
890426	200	.	.	.	.	.	.	.	.	.
	600	.	.	.	.	.	.	.	.	.
	1000	0	0	0	1	4.5	1,895	0	1,692	846
	1400	0	0	0	0	1.9	1,512	0	0	0
	1800	0	0	0	0	1.7	1,484	0	0	0
	2200	0	0	0	0	2.6	1,610	0	0	0
890427	200	0	0	0	0	3.5	1,743	0	0	0
	600	0	0	0	0	4.8	1,941	0	0	0
	1000	.	.	.	.	5.4	2,034	.	.	.
	1400	0	0	0	0	5.4	2,034	0	0	0
	1800	0	0	0	0	5.0	1,972	0	0	0
	2200	0	0	0	0	3.8	1,788	0	0	0
890428	200	0	0	0	0	2.8	1,639	0	0	0
	600	3	5	5	9	2.0	1,526	10,898	19,071	14,985
	1000	8	7	17	22	1.7	1,484	19,876	51,678	35,777
	1400	5	3	6	0	1.5	1,457	10,404	7,803	9,104
	1800	0	0	0	0	1.3	1,429	0	0	0
	2200	0	0	0	0	1.0	1,389	0	0	0

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg pro-duction Surface	Egg pro-duction Oblique	Egg pro-duction Combined
890429	200	0	0	0	0	0.8	1,362	0	0	0
	600	4	1	1	1	0.6	1,335	5,958	2,383	4,171
	1000	0	0	4	0	0.5	1,321	0	4,719	2,359
	1400	0	0	0	0	1.0	1,389	0	0	0
	1800	4	4	3	5	0.5	1,321	9,438	9,438	9,438
	2200	.	.	.	.	.	.	.	.	.
890430	200	.	.	.	.	.	.	.	.	.
	600	8	13	20	15	1.2	1,416	26,544	44,241	35,392
	1000	3	19	4	0	2.1	1,540	30,244	5,499	17,872
	1800	1	2	0	5	2.1	1,540	4,124	6,874	5,499
	1400	9	2	7	5	2.2	1,554	15,260	16,647	15,953
	2200	7	4	6	15	2.1	1,540	15,122	28,869	21,996
890501	200	.	.	.	.	2.0	1,526	.	.	.
	600	15	9	10	8	1.0	1,389	29,758	22,318	26,038
	1000	11	19	16	16	1.3	1,429	38,285	40,837	39,561
	1400	14	9	12	5	1.2	1,416	29,072	21,488	25,280
	1800	3	4	.	.	2.1	1,540	9,623	.	9,623
	2200	4	8	4	16	3.5	1,743	18,672	31,120	24,896
890502	200	.	.	.	.	.	.	.	.	.
	600	14	15	11	5	5.5	2,050	53,067	29,279	41,173
	1000	4	12	11	17	5.9	2,112	30,170	52,797	41,484
	1400	4	3	1	7	6.4	2,191	13,691	15,647	14,669
	1800	3	4	3	4	8.3	2,494	15,584	15,584	15,584
	2200	1	0	0	0	10.8	2,901	2,591	0	1,295
890503	200	0	0	0	3	12.1	3,124	0	8,367	4,183
	600	0	0	0	3	13.0	3,284	0	8,796	4,398
	1000	0	0	0	0	13.5	3,375	0	0	0
	1400	0	0	0	0	13.6	3,393	0	0	0
	1800	0	0	1	0	13.8	3,430	0	3,062	1,531
	2200	0	0	0	0	14.0	3,470	0	0	0

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890504	200	2	0	0	0	14.5	3,572	6,378	0	3,189
	600	2	3	0	2	14.3	3,531	15,761	6,304	11,033
	1000	0	0	0	1	14.4	3,551	0	3,171	1,585
	1400	0	0	0	0	13.8	3,430	0	0	0
	1800	0	0	0	1	14.0	3,470	0	3,098	1,549
	2200	0	0	0	0	14.2	3,510	0	0	0
890505	200	0	0	0	0	14.0	3,470	0	0	0
	600	0	0	0	0	14.3	3,531	0	0	0
	1000	0	0	0	0	14.5	3,572	0	0	0
	1400	2	1	3	1	14.6	3,592	9,622	12,830	11,226
	1800	0	0	0	0	14.5	3,572	0	0	0
	2200	0	0	0	0	14.8	3,634	0	0	0
890506	200	.	.	.	.	.	.	.	.	.
	600	0	0	1	0	14.7	3,613	0	3,226	1,613
	1000	0	0	0	0	14.7	3,613	0	0	0
	1400	0	0	0	0	14.8	3,634	0	0	0
	1800	0	0	0	0	14.8	3,634	0	0	0
	2200	0	0	0	0	11.8	3,071	0	0	0
890507	200	.	.	.	.	.	.	.	.	.
	600	.	.	.	.	.	.	.	.	.
	1000	0	0	0	0	13.8	3,430	0	0	0
	1400	0	0	0	0	13.8	3,430	0	0	0
	1800	0	0	0	0	14.9	3,656	0	0	0
	2200	0	0	0	0	14.9	3,656	0	0	0
890508	200	0	0	0	0	14.8	3,634	0	0	0
	600	0	0	0	0	14.8	3,634	0	0	0
	1000	0	0	0	0	14.8	3,634	0	0	0
	1400	0	0	0	0	14.6	3,592	0	0	0
	1800	0	0	0	0	14.8	3,634	0	0	0
	2200	0	0	0	0	14.8	3,634	0	0	0

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890509	200	0	0	0	0	14.8	3,634	0	0	0
	600	0	0	0	0	14.8	3,634	0	0	0
	1000	0	0	0	0	14.8	3,634	0	0	0
	1400	0	0	0	0	14.7	3,613	0	0	0
	1800	0	0	0	0	14.8	3,634	0	0	0
	2200	0	0	0	0	14.8	3,634	0	0	0
890510	200	0	0	0	0	14.8	3,634	0	0	0
	600	0	0	0	0	14.8	3,634	0	0	0
	1000	0	0	0	0	14.8	3,634	0	0	0
	1400	0	0	0	0	14.8	3,634	0	0	0
	1800	0	0	0	0	14.8	3,634	0	0	0
	2200	0	0	0	0	14.8	3,634	0	0	0
890511	200	0	0	0	0	14.8	3,634	0	0	0
	600	0	0	0	0	14.8	3,634	0	0	0
	1000	0	0	0	0	14.8	3,634	0	0	0
	1400	0	0	0	0	14.8	3,634	0	0	0
	1800	2	0	0	1	14.8	3,634	6,490	3,245	4,867
	2200	0	1	0	0	14.8	3,634	3,245	0	1,622
890512	200	0	0	0	0	15.0	3,677	0	0	0
	600	0	0	0	0	15.0	3,677	0	0	0
	1000	0	0	0	0	14.9	3,656	0	0	0
	1400	0	0	0	0	14.8	3,634	0	0	0
	1800	0	0	0	0	14.8	3,634	0	0	0
	2200	0	0	0	0	14.8	3,634	0	0	0
890513	200	0	0	0	0	14.8	3,634	0	0	0
	600	0	0	0	0	14.8	3,634	0	0	0
	1000	0	0	0	0	14.7	3,613	0	0	0
	1400	0	0	0	0	14.7	3,613	0	0	0
	1800	0	0	0	0	14.7	3,613	0	0	0
	2200	0	0	0	0	14.7	3,613	0	0	0

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg pro-duction Surface	Egg pro-duction Oblique	Egg pro-duction Combined
890514	200	0	0	0	0	14.7	3,613	0	0	0
	600	0	0	0	0	14.7	3,613	0	0	0
	1400	0	0	0	0	14.7	3,613	0	0	0
	1000	0	0	0	0	14.8	3,634	0	0	0
	1800	0	0	0	0	14.8	3,634	0	0	0
	2200	0	0	0	0	14.8	3,634	0	0	0
890515	200	0	0	0	0	14.7	3,613	0	0	0
	600	0	0	0	0	14.8	3,634	0	0	0
	1000	0	0	0	0	14.8	3,634	0	0	0
	1400	0	0	0	0	14.5	3,572	0	0	0
	1800	0	1	1	0	14.7	3,613	3,226	3,226	3,226
	2200	0	0	0	0	14.7	3,613	0	0	0
890516	200	.	.	.	.	.	.	.	.	.
	600	0	0	0	0	14.8	3,634	0	0	0
	1000	0	0	0	0	14.8	3,634	0	0	0
	1400	0	0	0	0	14.8	3,634	0	0	0
	1800	0	0	0	0	14.8	3,634	0	0	0
	2200	0	0	0	0	14.8	3,634	0	0	0
890517	200	0	0	0	0	14.8	3,634	0	0	0
	600	0	0	0	0	14.7	3,613	0	0	0
	1000	0	0	0	0	14.8	3,634	0	0	0
	1400	0	0	0	0	14.5	3,572	0	0	0
	1800	0	0	0	0	14.7	3,613	0	0	0
	2200	0	0	0	0	14.7	3,613	0	0	0
890518	200	0	0	0	0	14.7	3,613	0	0	0
	600	0	0	0	0	14.7	3,613	0	0	0
	1000	0	0	0	0	14.7	3,613	0	0	0
	1400	0	0	2	0	14.5	3,572	0	6,378	3,189
	1800	0	1	2	1	14.7	3,613	3,226	9,678	6,452
	2200	0	3	0	0	14.7	3,613	9,678	0	4,839

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890519	200	0	0	0	0	14.7	3,613	0	0	0
	600	0	0	1	8	14.7	3,613	0	29,035	14,518
	1000	0	2	1	0	14.8	3,634	6,490	3,245	4,867
	1400	3	0	5	1	14.8	3,634	9,734	19,469	14,602
	1800	0	5	0	3	14.7	3,613	16,131	9,678	12,905
	2200	2	5	0	1	14.7	3,613	22,583	3,226	12,905
890520	200	1	0	0	0	14.7	3,613	3,226	0	1,613
	600	2	2	5	3	14.6	3,592	12,830	25,659	19,244
	1000	5	3	5	2	14.5	3,572	25,512	22,323	23,918
	1400	2	12	0	3	14.5	3,572	44,646	9,567	27,107
	1800	4	1	3	1	14.6	3,592	16,037	12,830	14,433
	2200	2	2	0	7	14.6	3,592	12,830	22,452	17,641
890521	200	0	4	3	1	14.6	3,592	12,830	12,830	12,830
	600	0	3	1	5	14.5	3,572	9,567	19,134	14,351
	1000	4	9	22	29	14.5	3,572	41,457	162,640	102,049
	1400	23	28	28	35	14.5	3,572	162,640	200,908	181,774
	1800	2	8	5	8	14.5	3,572	31,890	41,457	36,674
	2200	1	1	3	1	14.5	3,572	6,378	12,756	9,567
890522	200	4	2	1	5	14.5	3,572	19,134	19,134	19,134
	600	39	11	19	51	14.6	3,592	160,371	224,519	192,445
	1000	18	43	45	41	14.5	3,572	194,530	274,255	234,393
	1400	9	14	28	10	14.4	3,551	72,922	120,480	96,701
	1800	18	14	9	15	14.5	3,572	102,049	76,536	89,292
	2200	6	5	5	9	14.5	3,572	35,079	44,646	39,863
890523	200	2	2	11	9	14.5	3,572	12,756	63,780	38,268
	600	183	93	103	361	14.7	3,613	890,420	1,496,938	1,193,679
	1000	98	42	66	140	14.4	3,551	443,875	653,130	548,503
	1400	41	83	55	53	14.4	3,551	393,146	342,418	367,782
	1800	34	8	4	17	14.7	3,613	135,499	67,749	101,624
	2200	11	33	.	.	14.7	3,613	141,951	.	141,951

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890524	200	42	21	31	59	14.7	3,613	203,248	290,354	246,801
	600	81	88	90	78	14.7	3,613	545,221	541,995	543,608
	1000	86	79	83	48	14.7	3,613	532,316	422,627	477,472
	1400	16	65	29	32	14.6	3,592	259,800	195,652	227,726
	1800	7	2	6	9	14.8	3,634	29,203	48,672	38,938
	2200	0	0	4	6	14.8	3,634	0	32,448	16,224
890525	200	2	6	2	3	14.8	3,634	25,959	16,224	21,091
	600	22	15	13	10	14.8	3,634	120,058	74,631	97,345
	1000	3	6	9	7	14.8	3,634	29,203	51,917	40,560
	1400	8	11	21	16	14.8	3,634	61,652	120,058	90,855
	1800	1	5	3	5	14.7	3,613	19,357	25,809	22,583
	2200	0	0	3	0	14.7	3,613	0	9,678	4,839
890526	200	5	7	9	5	14.7	3,613	38,714	45,166	41,940
	600	5	36	40	16	14.7	3,613	132,273	180,665	156,469
	1000	39	52	.	.	14.7	3,613	293,581	.	293,581
	1400	3	8	5	1	14.8	3,634	35,693	19,469	27,581
	1800	7	2	3	6	14.7	3,613	29,035	29,035	29,035
	2200	87	94	113	69	14.7	3,613	583,935	587,161	585,548
890527	200	168	247	163	196	14.7	3,613	1,338,856	1,158,192	1,248,524
	600	206	141	175	234	14.7	3,613	1,119,478	1,319,500	1,219,489
	1000	123	92	69	63	14.7	3,613	693,624	425,853	559,739
	1400	10	15	10	19	14.7	3,613	80,654	93,559	87,106
	1800	5	11	4	13	14.7	3,613	51,619	54,845	53,232
	2200	12	13	17	25	14.7	3,613	80,654	135,499	108,076
890528	200	18	44	55	21	14.7	3,613	200,022	245,188	222,605
	600	45	23	18	14	14.7	3,613	219,379	103,237	161,308
	1000	2	15	5	7	14.7	3,613	54,845	38,714	46,779
	1400	5	4	7	5	14.7	3,613	29,035	38,714	33,875
	1800	0	0	1	0	14.7	3,613	0	3,226	1,613
	2200	4	12	12	15	14.7	3,613	51,619	87,106	69,362

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890529	200	9	17	4	24	14.7	3,613	83,880	90,332	87,106
	600	5	8	8	3	14.7	3,613	41,940	35,488	38,714
	1000	0	3	5	2	14.7	3,613	9,678	22,583	16,131
	1400	1	0	2	5	14.7	3,613	3,226	22,583	12,905
	1800	7	3	4	3	14.7	3,613	32,262	22,583	27,422
	2200	4	20	10	8	14.7	3,613	77,428	58,071	67,749
890530	200	10	13	16	14	14.4	3,551	72,922	95,116	84,019
	600	15	6	5	4	14.3	3,531	66,197	28,370	47,283
	1000	6	10	18	13	12.0	3,106	44,370	85,967	65,168
	1400	11	0	4	8	10.7	2,885	28,333	30,909	29,621
	1800	3	3	2	1	10.0	2,769	14,833	7,417	11,125
	2200	2	2	5	3	9.3	2,655	9,481	18,962	14,222
890531	200	30	35	24	56	8.7	2,558	148,450	182,707	165,578
	600	80	40	102	159	8.0	2,445	261,986	569,819	415,902
	1000	82	83	56	75	7.5	2,365	348,430	276,632	312,531
	1400	31	32	48	25	7.2	2,317	130,348	151,038	140,693
	1800	24	41	84	62	6.8	2,254	130,801	293,799	212,300
	2200	141	127	61	137	6.5	2,206	527,960	390,060	459,010
890601	200	53	71	72	75	6.1	2,143	237,294	281,308	259,301
	600	43	21	19	21	5.7	2,081	118,891	74,307	96,599
	1000	15	23	18	12	5.0	1,972	66,904	52,819	59,861
	1400	7	3	30	14	5.3	2,018	18,021	79,294	48,658
	1800	9	14	19	13	5.0	1,972	40,494	56,340	48,417
	2200	28	24	45	28	6.5	2,206	102,440	143,810	123,125
890602	200	9	6	7	15	8.3	2,494	33,395	48,979	41,187
	600	4	3	3	11	9.5	2,687	16,795	33,590	25,192
	1000	0	0	2	3	9.8	2,736	0	12,215	6,108
	1400	0	2	1	2	9.8	2,736	4,886	7,329	6,108
	1800	5	6	1	6	10.4	2,835	27,843	17,718	22,780
	2200	4	5	0	0	10.8	2,901	23,315	0	11,657

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890603	200	0	2	2	0	10.9	2,918	5,211	5,211	5,211
	600	2	3	1	5	9.6	2,704	12,069	14,483	13,276
	1000	0	0	0	0	7.4	2,349	0	0	0
	1400	1	0	0	0	8.0	2,445	2,183	0	1,092
	1800	0	0	0	0	7.6	2,381	0	0	0
	2200	0	0	1	1	5.3	2,018	0	3,604	1,802
890604	200	1	1	2	3	4.0	1,818	3,247	8,117	5,682
	600	0	2	1	0	2.7	1,625	2,901	1,451	2,176
	1000	0	2	0	2	2.3	1,568	2,800	2,800	2,800
	1400	3	4	3	1	1.8	1,498	9,362	5,350	7,356
	1800	3	5	7	10	0.5	1,321	9,438	20,055	14,747
	2200	.	.	.	.	0.0	1,255	.	.	.
890605	200	3	10	12	3	-0.1	1,241	14,409	16,626	15,517
	600	3	5	1	4	-1.5	1,057	7,549	4,718	6,134
	1000	0	0	0	0	-1.4	1,070	0	0	0
	1400	0	0	0	0	-1.4	1,070	0	0	0
	1800	0	0	0	0	-1.9	1,005	0	0	0
	2200	0	1	.	.	-1.9	1,005	897	.	897
890606	200	0	0	.	.	-0.4	1,202	0	.	0
	600	1	1	0	0	-0.7	1,162	2,075	0	1,037
	1000	0	0	1	0	-0.9	1,136	0	1,014	507
	1400	0	0	0	0	-0.8	1,149	0	0	0
	1800	4	4	1	0	-0.8	1,149	8,206	1,026	4,616
	2200	2	8	5	4	-0.8	1,149	10,257	9,231	9,744
890607	200	1	3	0	0	-0.8	1,149	4,103	0	2,051
	600	1	2	1	0	-1.5	1,057	2,831	944	1,887
	1000	3	1	0	0	-1.5	1,057	3,775	0	1,887
	1400	0	0	1	1	-1.5	1,057	0	1,887	944
	1800	2	1	0	0	-1.3	1,083	2,901	0	1,451
	2200	1	0	0	0	0.2	1,281	1,144	0	572

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890608	200	0	0	0	0	0.2	1,281	0	0	0
	600	0	0	0	0	3.2	1,698	0	0	0
	1000	0	1	0	0	3.2	1,698	1,516	0	758
	1400	0	0	0	0	3.9	1,803	0	0	0
	1800	0	0	0	0	4.1	1,834	0	0	0
	2200	4	5	1	1	4.3	1,864	14,980	3,329	9,155
890609	200	1	0	1	1	4.3	1,864	1,664	3,329	2,497
	600	1	1	0	0	4.6	1,910	3,411	0	1,706
	1000	0	0	0	0	4.7	1,926	0	0	0
	1400	0	0	0	0	4.7	1,926	0	0	0
	1800	1	0	1	0	4.8	1,941	1,733	1,733	1,733
	2200	1	0	0	0	4.8	1,941	1,733	0	867
890610	200	0	0	0	0	4.8	1,941	0	0	0
	600	0	0	0	0	5.0	1,972	0	0	0
	1000	0	0	0	0	4.8	1,941	0	0	0
	1400	0	0	0	0	4.8	1,941	0	0	0
	1800	0	0	0	0	4.8	1,941	0	0	0
	2200	0	0	0	0	4.8	1,941	0	0	0
890611	200	.	.	.	.	.	.	.	.	.
	600	0	0	0	0	4.8	1,941	0	0	0
	1000	0	0	0	0	4.8	1,941	0	0	0
	1400	0	0	0	0	4.8	1,941	0	0	0
	1800	0	0	0	0	4.8	1,941	0	0	0
	2200	0	0	0	0	4.8	1,941	0	0	0
890612	200	0	0	0	0	4.8	1,941	0	0	0
	600	0	0	1	0	4.8	1,941	0	1,733	867
	1000	0	0	0	0	4.8	1,941	0	0	0
	1400	0	0	0	0	4.8	1,941	0	0	0
	1800	0	0	0	0	4.8	1,941	0	0	0
	2200	.	.	.	.	5.2	2,003	.	.	.

Table 9. *continued*

Date	Time	Egg count Surface (rep A)	Egg count Surface (rep B)	Egg count Oblique (rep A)	Egg count Oblique (rep B)	River stage (feet)	Cross-section (sq.ft.)	Egg production Surface	Egg production Oblique	Egg production Combined
890613	200	.	.	.	.	5.2	2,003	.	.	.
	600	0	0	0	0	6.4	2,191	0	0	0
	1000	0	0	0	0	8.8	2,574	0	0	0
	1400	0	0	0	0	9.2	2,639	0	0	0
	1800	0	0	0	0	9.4	2,671	0	0	0
	2200	0	0	0	0	9.6	2,704	0	0	0
890614	200	0	0	0	0	9.8	2,736	0	0	0
	600	0	0	0	0	10.3	2,818	0	0	0
	1000	0	0	0	0	10.3	2,818	0	0	0
	1400	0	0	0	0	10.3	2,818	0	0	0
	1800	0	0	0	0	10.4	2,835	0	0	0
	2200	0	0	0	0	10.5	2,852	0	0	0
890615	200	0	0	0	0	10.5	2,852	0	0	0
	600	0	0	0	0	10.5	2,852	0	0	0
	1000	0	0	0	0	10.3	2,818	0	0	0

Table 10. Daily egg production of striped bass at Barnhill's Landing, Roanoke River, NC, in 1989, estimated by two methods and two depths.

Date	Number of Samples	Total eggs surface only (trip method)	Total eggs oblique only (trip method)	Total eggs all depths (trip method)	Total eggs surface only (Hassler)	Total eggs oblique only (Hassler)	Total eggs all depths (Hassler)
890317	0	.	.	.	.	.	.
890323	0	.	.	.	.	.	.
890329	0	.	.	.	.	.	.
890406	4	.	.	.	.	.	.
890412	4	.	.	.	.	.	.
890414	0	.	.	.	.	.	.
890415	0	.	.	.	.	.	.
890416	16	157,193	0	78,596	157,193	0	78,596
890417	24	0	0	0	0	0	0
890418	24	0	0	0	0	0	0
890419	20	0	0	0	0	0	0
890420	24	0	0	0	0	0	0
890421	24	0	182,367	91,184	0	183,267	91,634
890422	24	0	0	0	0	0	0
890423	24	0	0	0	0	0	0
890424	20	0	0	0	0	0	0
890425	16	0	0	0	0	0	0
890426	16	0	121,816	60,908	0	104,483	52,241
890427	20	0	0	0	0	0	0
890428	24	1,976,584	3,770,573	2,873,578	1,975,890	3,760,565	2,868,227
890429	20	886,837	952,722	919,779	899,597	968,797	934,197
890430	20	5,258,595	5,882,701	5,570,648	5,307,658	6,010,142	5,658,900
890501	18	7,223,676	8,335,040	7,223,002	7,440,172	8,428,320	7,879,349
890502	20	6,630,021	6,526,572	6,578,296	7,249,576	7,128,750	7,189,163
890503	24	0	970,804	485,402	0	1,003,728	501,864
890504	24	1,062,690	603,498	833,094	1,053,124	601,785	827,454
890505	24	461,871	615,828	538,849	457,930	610,574	534,252
890506	20	0	185,828	92,914	0	180,679	90,340
890507	16	0	0	0	0	0	0
890508	24	0	0	0	0	0	0
890509	24	0	0	0	0	0	0
890510	24	0	0	0	0	0	0
890511	24	467,258	155,753	311,505	467,258	155,753	311,505
890512	24	0	0	0	0	0	0
890513	24	0	0	0	0	0	0
890514	24	0	0	0	0	0	0
890515	24	154,857	154,857	154,857	154,858	154,858	154,858

Table 10. *continued*

Date	Number of Samples	Total eggs surface only (trip method)	Total eggs oblique only (trip method)	Total eggs all depths (trip method)	Total eggs surface only (Hassler)	Total eggs oblique only (Hassler)	Total eggs all depths (Hassler)
890516	20	0	0	0	0	0	0
890517	24	0	0	0	0	0	0
890518	24	619,428	770,719	695,074	618,239	772,799	695,519
890519	24	2,637,048	3,103,410	2,870,229	2,637,645	3,103,112	2,870,378
890520	24	5,523,929	4,455,924	4,989,927	5,537,258	4,460,569	4,998,913
890521	24	12,708,684	21,586,984	17,147,834	12,717,366	21,604,200	17,160,783
890522	24	28,036,305	36,459,732	32,248,019	28,012,436	36,431,474	32,221,955
890523	22	96,847,896	151,144,611	114,807,723	96,812,007	151,026,731	121,455,063
890524	24	75,350,522	73,524,570	74,437,546	75,487,716	73,627,649	74,557,683
890525	24	12,299,091	14,319,398	13,309,244	12,280,878	14,301,782	13,291,330
890526	22	53,435,520	49,622,634	54,439,851	53,477,171	49,664,016	51,743,918
890527	24	161,515,856	152,998,721	157,257,288	161,515,856	152,998,721	157,257,288
890528	24	26,635,405	24,777,121	25,706,263	26,635,405	24,777,121	25,706,263
890529	24	11,923,989	12,078,846	12,001,418	11,923,989	12,078,846	12,001,418
890530	24	11,334,647	12,803,648	12,069,148	10,701,231	12,286,598	11,493,914
890531	24	74,303,381	89,475,411	81,889,396	75,377,001	89,825,944	82,601,472
890601	24	28,034,389	33,018,434	30,526,412	27,529,283	32,397,806	29,963,544
890602	24	5,099,262	5,751,978	5,425,620	5,150,997	5,970,474	5,560,736
890603	24	934,246	1,118,324	1,026,285	846,596	1,058,245	952,420
890604	20	1,598,264	2,175,724	1,886,994	1,635,242	2,258,191	1,946,716
890605	22	1,097,075	1,229,436	1,082,334	1,013,250	1,105,363	1,055,120
890606	22	985,825	649,219	763,421	992,237	654,876	838,891
890607	24	708,182	135,888	422,035	716,138	143,228	429,683
890608	24	791,814	159,790	475,802	726,977	145,395	436,186
890609	24	410,001	242,976	326,488	410,989	246,593	328,791
890610	24	0	0	0	0	0	0
890611	20	0	0	0	0	0	0
890612	20	0	99,824	49,912	0	100,354	50,177
890613	20	0	0	0	0	0	0
890614	24	0	0	0	0	0	0
890615	12	0	0	0	0	0	0
		============	============	============	============	============	============
		637,110,340	720,161,682	671,666,876	637,919,162	720,331,787	676,790,744

APPENDIX

Table A-1. List of Counties Enumerated in Figure 1.

1-12 (Virginia)		13-24 (North Carolina)	
1.	Roanoke	13.	Stokes
2.	Franklin	14.	Rockingham
3.	Patrick	15.	Caswell
4.	Henry	16.	Person
5.	Bedford	17.	Granville
6.	Pittsylvania	18.	Vance
7.	Campbell	19.	Warren
8.	Halifax	20.	Halifax
9.	Charlotte	21.	Northampton
10.	Lunenburg	22.	Bertie
11.	Mecklenburg	23.	Martin
12.	Brunswick	24.	Washington

Table A-2. Location of the historical sampling locations used by W.W. Hassler and co-workers (1959-1987), Rulifson (1989), and this study.

Location	River Mile	Latitude	Longitude
Halifax	120	77°35'5"E	36°20'6"N
Johnson's Landing	118.5	77°18'23"E	36°33'20"N
Barnhill's Landing	117	77°18'23"E	36°32'15"N
Pollock's Ferry	105	77°24'30"E	36°15'30"N
Palmyra	78.5	77°19'30"E	36°4'32"N

Table A-3. Hourly sample grid for the 1989 striped bass egg study at Barnhill's Landing, Roanoke River, North Carolina.

		Hour of Day																								
DAY	DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
0	890317	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	890323	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
12	890329	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20	890406	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	4
26	890412	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	4
28	890414	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
29	890415	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
30	890416	.	.	.	.	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	16
31	890417	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
32	890418	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
33	890419	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	.	4	.	.	.	4	.	.	20
34	890420	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
35	890421	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
36	890422	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
37	890423	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
38	890424	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
39	890425	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	.	.	.	.	16
40	890426	.	.	.	.	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	16
41	890427	.	4	.	.	.	4	.	.	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
42	890428	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
43	890429	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	20
44	890430	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
45	890501	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	2	.	.	.	4	.	.	18
46	890502	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
47	890503	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
48	890504	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
49	890505	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
50	890506	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
51	890507	.	.	.	.	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	16
52	890508	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
53	890509	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
54	890510	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
55	890511	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
56	890512	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
57	890513	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
58	890514	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
59	890515	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
60	890516	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
61	890517	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
62	890518	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
63	890519	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
64	890520	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
65	890521	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
66	890522	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
67	890523	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	2	.	.	22
68	890524	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
69	890525	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
70	890526	.	4	.	.	.	4	.	.	.	2	.	.	.	4	.	.	.	4	.	.	.	4	.	.	22
71	890527	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
72	890528	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24

Table A-3. *continued*

		Hour of Day																								
DAY	DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
73	890529	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
74	890530	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
75	890531	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
76	890601	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
77	890602	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
78	890603	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
79	890604	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	20
80	890605	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	2	.	.	22
81	890606	.	2	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	22
82	890607	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
83	890608	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
84	890609	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
85	890610	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
86	890611	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
87	890612	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	20
88	890613	.	.	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	20
89	890614	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	.	4	.	.	24
90	890615	.	4	.	.	.	4	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12

Code listing for Appendix Tables A-4 and A-5.

Variable name	Description
PAGE	page number of the original field sheet.
DATE	YY/MM/DD.
TIME	military time
ATEMP	air temperature (°C).
WTEMP	surface water temperature (°C).
PH	pH of surface water (standard units).
DO	dissolved oxygen of surface waters (mg/L).
TDS	total dissolved solids.
SECCHI	secchi disk visibility (cm).
WVEL	surface water velocity (cm/second).
RSTAGE	river stage (relative measurement, feet and tenths).
SREVS	surface flowmeter revolutions (number in five minutes).
OREVS	oblique flowmeter revolutions (number in five minutes).
ASURF	number of eggs in surface net A.
BSURF	number of eggs in surface net B.
AOBL	number of eggs in oblique net A.
BOBL	number of eggs in oblique net B.
ASVIA	number of viable eggs in surface net A.
BSVIA	number of viable eggs in surface net B.
AOVIA	number of viable eggs in oblique net A.
BOVIA	number of viable eggs in oblique net B.
ST1	number of eggs less than 10 hours old (17°C criteria).
ST2	number of eggs 10-18 hours old (17°C criteria).
ST3	number of eggs 20-28 hours old (17°C criteria).
ST4	number of eggs 30+ hours old (17°C criteria).
HATCH	number of striped bass larvae.

Table A-4. Water quality data collected at Barnhills Landing, Roanoke River, NC, from 17 March to 15 April 1989.

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
1	890317	1437		10.0	8.0	8	9		110	63.60		1448	
2	890323	1030	4.0	8.5	8.2	10.9	12	2	130	92.80		2357	
3	890329	1043	22.0	12.0	7.1		8	4	90				
4	890406	1042	14.0	13.5	7.4	9	9	5	40	71.12		4316	1775
5	890412	1035	13.0	11.0	7.5	7	9	5	80	108.30		4966	6992
6	890414	1800	20.0	13.0	7.4	7	8	4	75	107.59			
7	890414	2200	17.0	13.0	7.2	7.5	8	4					
8	890415	600											
9	890415	1000											
10	890415	1800	15.0	13.0	7.3	7	8	4					
11	890416	1000	21.0	13.0		7	9	4	60	69.49	8.0	1697	3806
12	890416	1400	21.0	14.0		8	8	4	70	70.71	8.0	3848	3230
13	890416	1800	19.0	13.5		8	9	4	70	71.93	8.0	3747	3378
14	890416	2200	13.0	14.0		7	10	5		76.50	8.0	3466	3278
15	890417	200	11.0	14.0		8	10	5			8.0	4452	
16	890417	600	8.0	14.0		8	10	5		92.77	8.0	3206	3202
17	890417	1000	16.0	13.0		8	9	4	80		8.0		3505
18	890417	1400	19.0	13.0	7.6	7	5	4	70	86.60	8.0	2750	3060
19	890417	1800	21.0	14.0	7.7	8	8	4	60	89.27	7.0	2489	3463
20	890417	2200	18.0	14.0	7.5	8	9	5		72.57	6.0	4291	2154
21	890418	200	16.0	14.0	7.5	8	9	4		81.13	6.1	4784	3006
22	890418	600	15.0	14.0	7.5	8	10	5		91.18	5.8	3168	3527
23	890418	1000	19.0	13.0	7.7	8	8	4	65	82.38	5.9	3918	3682
24	890418	1400	28.0	14.0	7.8	8	5	4	65	78.73	6.0	4431	3886
25	890418	1800	25.0	15.0	7.6	8	8	4	60	78.73	6.1	4677	4132
26	890418	2200	20.0	15.0	7.8	8	9	5		79.61	6.1	4580	3583
27	890419	200	17.0	15.0	7.4	7	9	5		83.67	6.1	5718	4447
28	890419	600	16.0	14.5	7.6	8	9	5		86.38	6.0	4235	3863
29	890419	1000	19.0	14.0	7.9	8	9	5	60	83.34	6.1	4940	5175
30	890419	1400	21.0	15.0	7.5	8	8	4	60	73.07	6.2	4156	2957
31	890419	1800	12.0	15.0	7.8	8	9	5	60	84.12	6.1	4050	4291
32	890419	2200	14.0	15.0	7.6	8	10	5		90.22	6.1	4249	4086
33	890420	200	11.0	15.0	7.7	8	9	5		86.73	6.1	4316	4837

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
34	890420	600	11.0	14.5	7.5	8	10	5		86.03	6.1	4405	3945
35	890420	1000	14.5	14.0	7.6	7	10	5	70	75.66	6.0	5120	3181
36	890420	1400	16.0	14.0	7.7	7	8	4	70	84.67	6.0	4219	3654
37	890420	1800	18.0	15.0	7.6	8	9	4	70	78.73	6.0	3975	4087
38	890420	2200	16.0	14.0	7.8	7	10	5		84.67	6.0	4245	3828
39	890421	200	9.0	14.0	7.8	7	11	8		86.38	5.9	4195	5178
40	890421	600	1.0	14.0	7.5	8	11	5		82.70	6.0	5393	3987
41	890421	1000	19.0	14.0	7.0	8	9	5	65	81.75	6.1	5080	4390
42	890421	1400	20.0	14.0	7.6	7	8	4	70	88.53	6.4	4598	3833
43	890421	1800	18.0	15.0	7.6	7	9	4	70	78.02	6.0	4812	4318
44	890421	2200	13.0	15.0	7.7	8	10	5		85.34	6.0	4330	4480
45	890422	200	9.0	15.0	7.6	8	10	5		83.02	6.0	4112	3263
46	890422	600	9.0	14.0	7.6	8	11	5	60	88.32	5.8	4644	4071
47	890422	1000	14.0	14.0	7.7	7	10	5	70	85.00	6.3	4684	4762
48	890422	1400	27.0	14.0	7.7	7	8	4	60	86.38	5.8	4694	3808
49	890422	1800	20.0	15.0	7.6	7	9	4	70	86.86	5.8	4697	3828
50	890422	2200	15.0	15.0	7.6	7	10	5		84.00	5.8	3807	3678
51	890423	200	13.0	15.0	7.4	8	10	5		88.90	5.8	4800	4560
52	890423	600	12.0	15.0	7.3	8	11	5	60	89.91	5.1	4140	3943
53	890423	1000	15.0	15.0	7.5	7	9	4	70	88.17	5.9	4423	2850
54	890423	1400	16.0	14.0	7.7	7	8	4	70	83.67	4.8	4407	3532
55	890423	1800	18.0	15.5	7.5	7	6	4	70	83.67	4.5	4042	3907
56	890423	2200	15.0	15.0	7.5	7	7	5		96.11	4.5	3994	3476
57	890424	200											
58	890424	600	9.0	14.5	7.4	7	9	5	60	83.34	4.3	4234	3019
59	890424	1000	14.0	14.0	7.7	7	10	5	50	89.27	4.8	4982	4596
60	890424	1400	17.0	15.0	7.8	7	5	4	70	90.03	5.0	4597	3603
61	890424	1800	21.0	16.0	6.8	7	5	4	70	83.78	5.3	4686	4757
62	890424	2200	18.0	15.0	7.0	8	7	4		90.79	5.5	4531	3760
63	890425	200	14.0	15.0	7.6	7	7	5		92.36	5.6	3745	3664
64	890425	600	12.0	15.0	6.5	8	8	5	60	90.41	5.3	4545	3084
65	890425	1000	22.0	15.0	7.3	8	4	4	50	78.73	5.3	4999	3078
66	890425	1400	29.0	16.0	7.2	7	4	3	80	86.73	5.1	4199	3295
67	890425	1800											

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
68	890425	2200											
69	890426	200											
70	890426	600											
71	890426	1000	28.0	16.0	7.8	7	8	4	70	66.47	4.5	3782	3490
72	890426	1400	27.0	17.0	7.4	7	8	3	75	66.06	1.9	2730	3020
73	890426	1800	23.0	17.0		7	9	4	80	68.60	1.7	3782	2416
74	890426	2200	20.0	17.0		6	10	5		92.36	2.6	3778	3402
75	890427	200	17.0	17.0			8	5		86.03	3.5	8655	
76	890427	600	17.0	16.0		7	9	4	70	87.09	4.8	4890	4516
77	890427	1000	18.0	17.0		7	9	4			5.4		
78	890427	1400	24.0	17.0		7	7	4		81.13	5.4		
79	890427	1800	24.0	17.5	8.0	7	7	4	80	90.41	5.0	4493	3356
80	890427	2200	15.0	17.0		8	7	4		86.03	3.8	2491	3119
81	890428	200	18.0	16.0		7	4	5		63.31	2.8	2886	2321
82	890428	600	16.0	17.0		7	5	4	70	69.50	2.0	3188	3063
83	890428	1000	17.0	17.0		7	8	5	70	59.93	1.7	3344	2994
84	890428	1400	20.0	17.5		7			80	53.47	1.5	3208	2564
85	890428	1800	24.0	19.0	8.8	8	9	5	80	57.05	1.3	3372	2764
86	890428	2200	17.0	19.0	7.8	7	5	5		62.57	1.0	5920	1291
87	890429	200	16.0	18.5	7.6	7	9	5		61.84	0.8	3010	2019
88	890429	600	17.0	18.0	7.6	8	10	5	70	61.31	0.6	3264	2377
89	890429	1000	20.0	17.0		7	9	4	60	58.78	0.5	5257	2971
90	890429	1400	22.0	17.0		7	8	5	60	75.13	1.0	1183	3581
91	890429	1800	22.0	17.0	6.8	7	8	4	70	55.71	0.5	3260	2733
92	890429	2200	20.0	17.0		7	9	5					
93	890430	200	18.0	18.0	7.4	7	8	5					
94	890430	600	17.0	17.5	6.8	8	8	4	10	69.50	1.2	2946	3561
95	890430	1000	24.0	18.0	6.9	8	8	4	10	70.80	2.1	5010	3885
96	890430	1400	25.0	18.0	7.5	7	6	4	10	66.06	2.2	3523	3034
97	890430	1800	22.5	19.0	6.7	7	7	4	20	60.44	2.1	3381	3009
98	890430	2200	20.0	19.0	7.5	8	8	4		70.18	2.1	3496	3400
99	890501	200	19.0	18.0	7.4	8	8	4			2.0		
100	890501	600	19.0	19.0	6.7	8	8	4	30	56.59	1.0	2500	2408
101	890501	1000	21.0	18.0	7.0	7	7	4	40	63.31	1.3	2886	2687

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
102	890501	1400	25.0	18.0	7.0	7	7	4	40	59.27	1.2	3484	1812
103	890501	1800	24.0	19.0	6.8	8	8	4	40	76.75	2.1	3514	
104	890501	2200	20.0	18.0	7.2	7	8	4		68.38	3.5	3369	3535
105	890502	200	19.0	18.0	7.2	8	8	5					
106	890502	600	18.0	18.0	8.6	8	8	4	40	85.34	5.5	4644	3784
107	890502	1000	18.0	18.0	8.7	8	7	4	40	80.51	5.9	5312	6432
108	890502	1400	24.0	19.0	8.2	8	6	3	30	86.73	6.4	4566	4034
109	890502	1800	20.0	19.0	8.6	8	6	4	30	95.68	8.3	7130	5153
110	890502	2200	16.0	18.0		8	8	4		112.29	10.8	4944	6068
111	890503	200	13.0	19.0		8	8	4		99.70	12.1	5680	5509
112	890503	600	12.0	18.0		8	10	5	20	107.76	13.0	5888	5139
113	890503	1000	15.0	18.0		8	8	4	20	96.54	13.5	5801	5602
114	890503	1400	16.0	17.0		7	7	4	40	117.23	13.6	6362	6767
115	890503	1800	18.0	17.0	7.3	8	7	4	40	122.62	13.8	6080	5815
116	890503	2200	12.0	16.0	6.8	8	10	4		113.49	14.0	5627	5398
117	890504	200	11.0	16.0		8	10	1		107.22	14.5	5867	6495
118	890504	600	10.0	17.0	7.7	8	10	5	45	98.78	14.3	6790	6188
119	890504	1000	17.0	17.0	7.4	8	9	4	40	78.15	14.4	2777	3121
120	890504	1400	22.0	18.0	7.4	7	7	3	70	112.89	13.8	3472	4122
121	890504	1800	20.0	18.0	7.4	8	9	4	70	103.57	14.0	5452	6167
122	890504	2200	18.0	18.0	7.6	8	9	4		106.68	14.2	6878	7252
123	890505	200	14.0	17.0	7.6	8	10	5		104.08	14.0	5713	3677
124	890505	600	14.0	17.0	8.1	8	10	4	70	100.17	14.3	6386	4937
125	890505	1000	18.0	17.0	8.0	8	10	4	70	95.68	14.5	5334	2121
126	890505	1400	19.0	18.0	7.6	7	8	4	60	98.32	14.6	6158	6459
127	890505	1800	19.0	18.0		8	8	4	75	100.17	14.5	6964	5826
128	890505	2200	19.0	18.0	8.6	7	8	4		103.57	14.8	5213	4749
129	890506	200	16.0	18.0	8.7	7	8	4					
130	890506	600	17.0	17.0	8.2	8	9	5	30	108.86	14.7	6831	6470
131	890506	1000	20.0	18.0	8.0	7	8	5	30	109.98	14.7	8474	9335
132	890506	1400	21.0	16.0	8.0	7	8	4	55	109.98	14.8	7100	7410
133	890506	1800	19.0	17.0	8.1	8	9	4	60	104.08	14.8	5287	6005
134	890506	2200	14.0	16.0	8.3	8	8	4		107.22	11.8	7704	5676
135	890507	200											

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
136	890507	600											
137	890507	1000	15.0	17.0	8.4	8	9	5	85	97.42	13.8	5718	16227
138	890507	1400	12.0	16.0	8.5	7	9	5	80	96.11	13.8	4772	4389
139	890507	1800	10.0	16.0	8.3	8	10	5	50	108.30	14.9	6068	5831
140	890507	2200	9.0	16.0	8.2	7	9	5		103.57	14.9	6646	7004
141	890508	200	8.0	15.0	8.2	8	8	5		111.71	14.8	2917	5553
142	890508	600	10.0	16.0	7.9	8	11	5	50	104.59	14.8	5750	5989
143	890508	1000	12.0	16.0	7.6	7	10	5	60	109.98	14.8	6359	7681
144	890508	1400	15.0	16.0	7.8	7	10	5	60	115.33	14.6	5093	6144
145	890508	1800	18.0	17.0	7.9	7	9	4	65	101.12	14.8	6012	5945
146	890508	2200	15.0	17.0	7.8	8	9	4		102.58	14.8	6082	5863
147	890509	200	12.0	16.0	7.9	7	8	4		91.57	14.8	6095	5996
148	890509	600	11.0	15.0	7.8	8	10	5	60	100.64	14.8	6014	5988
149	890509	1000	18.0	16.0	7.6	7	10	5	60	96.11	14.8	4528	6905
150	890509	1400	18.0	16.0	7.8	7	9	4	60	90.41	14.7	5337	5503
151	890509	1800	15.0	16.0	8.2	8	9	4	60	98.78	14.8	6129	5312
152	890509	2200	16.0	15.0	8.2	7	9	4		102.58	14.8	5519	5777
153	890510	200	16.0	15.0	8.6	8	7	4		94.83	14.8	6953	5667
154	890510	600	17.0	16.0	7.8	8	10	5	60	99.70	14.8	5841	6021
155	890510	1000	16.0	16.0	8.2	7	8	4	60	101.44	14.8	6674	5377
156	890510	1400	19.0	17.0	7.6	7	11	5	60	102.58	14.8	6213	3536
157	890510	1800	19.0	17.0	7.8	8	9	4	65	102.09	14.8	6045	5987
158	890510	2200	15.0	15.0	8.0	8	9	4		96.54	14.8	5900	5745
159	890511	200	12.0	15.0	8.2	8	8	4		96.11	14.8	5915	5815
160	890511	600	12.0	16.0	7.8	8	10	5	60	99.70	14.8	6841	5862
161	890511	1000	16.0	16.0	7.5	8	9	4	50	100.17	14.8	6069	6158
162	890511	1400	16.0	16.5	7.9	7	9	4	60	99.70	14.8	6375	6815
163	890511	1800	16.0	17.0	7.9	8	8	4	60	102.09	14.8	6052	6212
164	890511	2200	13.0	15.0	7.9	8	8	4		105.10	14.8	5331	5011
165	890512	200	12.0	15.0	8.4	8	8	3		87.44	15.0	4677	5328
166	890512	600	11.0	15.0	7.8	8	10	5	60	100.64	15.0	5421	5534
167	890512	1000	18.0	15.0	7.6	8	9	4	50	96.11	14.9	5807	5865
168	890512	1400	4.0	16.0	7.5	7	5	4	70	117.88	14.8	5349	5585
169	890512	1800	17.0	16.0	7.6	8	8	4	65	105.62	14.8	5852	6215

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
170	890512	2200	13.0	15.0	7.5	8	9	4		108.86	14.8	5403	5877
171	890513	200	15.0	16.0	8.5	8	6	3		109.98	14.8	6519	7152
172	890513	600	14.0	16.0	7.6	8	10	5	60	105.62	14.8	5823	5712
173	890513	1000	16.0	15.5	8.1	7	9	4	60	95.68	14.7	6581	6474
174	890513	1400	22.0	16.0	8.1	7	9	4	60	109.42	14.7	6936	6048
175	890513	1800	20.0	16.5	8.1	8	7	4	70	106.15	14.7	6036	6410
176	890513	2200	17.0	16.0	8.2	8	9	4		106.15	14.7	6379	5556
177	890514	200	15.5	15.0	7.9	8	7	3		87.80	14.7	6172	5023
178	890514	600	15.0	16.0	8.1	8	9	4	60	99.24	14.7	5755	5231
179	890514	1000	18.0	16.0	7.7	7	9	4	60	98.32	14.8	6118	6566
180	890514	1400	21.0	16.0	8.3	8	9	4	50	99.24	14.7	1489	11799
181	890514	1800	22.0	16.5	7.8	8	8	4	60	108.30	14.8	6804	6569
182	890514	2200	18.0	16.0	8.3	8	9	4		96.98	14.8	6552	5667
183	890515	200	16.0	15.0	8.3	7	7	3		111.71	14.7	6491	6838
184	890515	600	16.0	16.5	7.8	8	10	4	60	109.42	14.8	5862	6012
185	890515	1000	14.0	16.0	8.0	8	9	4	60	91.57	14.8	5984	6552
186	890515	1400	21.0	16.5	7.8	7	8	4	60	96.11	14.5	6096	6521
187	890515	1800	22.0	16.5	7.8	8	7	4	60	99.24	14.7	6589	5777
188	890515	2200	17.0	16.0	8.2	8	8	4		103.57	14.7	6195	6538
189	890516	200	14.5	16.5	8.2	8	7	3					
190	890516	600	16.0	15.5	8.1	8	9	5	50	103.07	14.8	4395	5070
191	890516	1000	18.0	16.0	8.0	8	9	4	60	105.10	14.8	5412	5828
192	890516	1400	18.0	16.5	7.9	8	8	4	60	103.57	14.8	5842	6022
193	890516	1800	20.0	16.5	8.1	8	8	4	60	84.00	14.8	4265	4126
194	890516	2200	16.0	16.0	8.3	8	8	4		108.30	14.8	5748	5407
195	890517	200	17.0	15.5	8.1	8	7	3		104.08	14.8	5557	5549
196	890517	600	18.0	15.5	8.0	8	7	4	60	104.08	14.7	6686	6266
197	890517	1000	19.0	15.5	7.9	8	9	4	50	106.15	14.8	5580	5007
198	890517	1400	19.0	16.0	8.2	7	8	4	55	110.55	14.5	6104	5635
199	890517	1800	20.0	16.5	8.0	8	8	4	60	107.76	14.7	5641	5923
200	890517	2200	18.0	16.5	8.0	8	8	4		106.86	14.7	6012	5822
201	890518	200	16.0	16.5	7.6	8	8	4		116.59	14.7	6138	6166
202	890518	600	18.0	16.0	7.9	8	9	5	60	104.59	14.7	5744	5966
203	890518	1000	19.0	16.5	8.2	8	9	4	55	97.42	14.7	5428	5334

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
204	890518	1400	24.5	15.0	8.0	9	6	3	70	99.24	14.5	6454	7610
205	890518	1800	20.5	17.0	8.1	8	7	3	70	103.57	14.7	6099	6282
206	890518	2200	20.0	16.0	8.1	8	9	4		112.89	14.7	6194	4894
207	890519	200	16.0	16.5	8.1	8	8	4		122.62	14.7	5133	6130
208	890519	600	18.0	16.5	7.9	8	8	4	60	105.62	14.7	5312	5872
209	890519	1000	22.0	16.5	8.0	7	8	4	60	103.07	14.8	5616	2699
210	890519	1400	26.0	17.0	8.1	7	9	4	60	110.55	14.8	5497	7418
211	890519	1800	23.0	17.5	8.1	8	9	5	70	106.68	14.7	5795	6298
212	890519	2200	17.0	17.0	7.8	8	9	4		119.20	14.7	6504	6495
213	890520	200	16.5	16.5	8.0	8	9	4		102.09	14.7	6317	6478
214	890520	600	17.0	16.5	7.7	8	9	4	70	105.62	14.6	7035	6059
215	890520	1000	20.0	17.0	8.2	8	9	5	70	106.15	14.5	6278	6474
216	890520	1400	29.0	17.5	8.0	8	8	4	80	99.70	14.5	5634	5256
217	890520	1800	25.0	17.5	8.3	8	9	4	75	104.68	14.6	5927	4885
218	890520	2200	22.0	18.0	7.9	7	8	4		108.30	14.6	6255	5698
219	890521	200	19.0	17.0	8.0	8	9	4		107.22	14.6	4703	5041
220	890521	600	17.0	17.0	8.1	8	8	4	75	110.55	14.5	7392	6916
221	890521	1000	24.5	18.3	8.2	9	9	4	90	131.70	14.5	6322	6848
222	890521	1400	26.0	18.2	7.6	8	8	4	110	132.52	14.5	6640	6212
223	890521	1800	27.5	18.2	7.6	8	7	4		137.65	14.5	5792	6142
224	890521	2200	19.0	18.0	7.9		9	5		108.86	14.5	6964	6936
225	890522	200	18.0	17.0	8.0	7	8	4		99.07	14.5	382	5428
226	890522	600	18.0	18.0	7.9	8	9	5	55	110.55	14.6	4499	6282
227	890522	1000	19.5	18.0	8.0	8	9	4	60	109.42	14.5	6938	8667
228	890522	1400	25.0	18.5	7.8	7	10		80	107.22	14.4	6781	5615
229	890522	1800	25.0	18.5	7.8	8	8	4	60	114.71	14.5	5590	6290
230	890522	2200	18.0	18.0	7.8	8	9	4		103.07	14.5	6800	6525
231	890523	200	18.0	18.5	7.8	8	9	4		106.15	14.5	6552	6428
232	890523	600	19.0	18.0	8.4	8	10	4	70	104.08	14.7	6702	7492
233	890523	1000	21.0	18.0	7.9	8	10	3	70	102.58	14.4	4830	6927
234	890523	1400	23.0	19.0	8.3	7	9	3	60	118.53	14.4	7126	6128
235	890523	1800	22.0	19.0	8.1	8	10	4	60	100.64	14.7	4242	4988
236	890523	2200	20.0	19.0	8.0	8	9	4		121.23	14.7	6066	
237	890524	200	16.0	18.0	8.2	8	10	4		111.71	14.7	7324	5725

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
238	890524	600	16.0	18.0	8.3	8	11	4	60	109.98	14.7	5463	6204
239	890524	1000	19.5	18.0	7.8	7	8	3	70	118.53	14.7	6134	5361
240	890524	1400	21.5	18.5	7.8	7	9	4	65	115.33	14.6	5980	5217
241	890524	1800	22.0	19.0	7.9	8	8	3	70	107.76	14.8	5954	4833
242	890524	2200	20.0	18.5	7.9	7	10	4		111.12	14.8	6348	6122
243	890525	200	19.0	17.0	7.9	8	10	4		102.09	14.8	5654	5776
244	890525	600	17.0	18.0	8.2	8	11	4	60	105.62	14.8	6052	6063
245	890525	1000	20.0	19.0	7.8	7	9	4	70	114.71	14.8	5074	5118
246	890525	1400	24.0	19.0	7.7	7	8	3	70	105.62	14.8	6375	5280
247	890525	1800	26.0	19.5	8.0	8	8	3	65	102.09	14.7	5940	5555
248	890525	2200	23.0	20.0	8.2	7	9	4		100.64	14.7	5564	6183
249	890526	200	23.0	19.5	7.9	8	8	4		130.90	14.7	5837	5500
250	890526	600	20.0	19.5	8.0	8	9	4	70	104.59	14.7	5134	5100
251	890526	1000	25.0	20.0	8.0	7	9	3	70	121.23	14.7	19799	
252	890526	1400	30.0	20.0	8.2	8	7	3	70	121.92	14.8		
253	890526	1800	26.0	20.0	7.7	8	9	4	70	116.59	14.7		
254	890526	2200	23.0	20.0	8.2	7	9	4		111.12	14.7		
255	890527	200	21.0	20.0	7.8	8	8	4		103.07	14.7		
256	890527	600	22.0	20.0	8.1	8	8	4	70	102.09	14.7		
257	890527	1000	21.5	20.0	7.9	8	8	4	70	106.15	14.7		
258	890527	1400	29.8	20.5	8.3	8	7	3	75	106.68	14.7		
259	890527	1800	22.0	20.0	7.9	7	9	3	65	101.60	14.7		
260	890527	2200	19.5	20.0	8.1	8	8	3		109.42	14.7		
261	890528	200	20.0	20.0	8.1	7	9	4		91.57	14.7		
262	890528	600	15.0	19.5	7.8	8	9	4	65	97.87	14.7		
263	890528	1000	18.0	19.0	8.0	8	9	4	70	85.00	14.7		
264	890528	1400	18.0	19.5	8.0	7	8	3	65	93.99	14.7		
265	890528	1800	19.0	20.0	7.8	8	8	3	60	98.32	14.7		
266	890528	2200	18.0	20.0	8.0	7	10	4		103.07	14.7		
267	890529	200	15.0	19.0	7.9	7	10	4		99.70	14.7		
268	890529	600	14.0	19.0	7.7	8	10	4	60	102.09	14.7		
269	890529	1000	25.0	19.0	7.9	8	10	4	70	102.12	14.7		
270	890529	1400	21.0	19.0	8.0	7	7	3	70	103.57	14.7		
271	890529	1800	24.0	20.5	8.1	8	8	3	65	108.86	14.7		

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
272	890529	2200	19.0	20.0	8.1	8	9	4		95.68	14.7		
273	890530	200	17.0	19.5	8.0	8	9	4		97.42	14.4		
274	890530	600	15.0	19.0	8.0	8	9	4	60	69.27	14.3		
275	890530	1000	24.0	19.5	8.1	8	9	4	55	69.95	12.0		
276	890530	1400	26.5	20.5	8.1	7	8	3	60	63.88	10.7		
277	890530	1800	25.0	20.5	8.1	7	7	3	55	62.57	10.0		
278	890530	2200	21.0	20.0	8.2	8	8	4		61.84	9.3		
279	890531	200	19.0	20.0	7.9	7	8	4		59.93	8.7		
280	890531	600	20.0	20.8	7.7	8	9	4	65	60.61	8.0		
281	890531	1000	26.0	21.0	7.4	8	9	4	60	69.73	7.5		
282	890531	1400	32.5	21.5	7.9	7	7	3	60	58.62	7.2		
283	890531	1800	31.0	21.5	8.1	7	9	3	70	59.10	6.8		
284	890531	2200	25.0	21.5	7.9	8	9	4		68.60	6.5		
285	890601	200	23.0	22.0	8.1	8	10	4		64.07	6.1		
286	890601	600	23.0	21.5	7.9	8	9	4	65	68.38	5.7		
287	890601	1000	30.0	22.5	8.0	7	8	4	60	76.20	5.0		
288	890601	1400	28.0	22.0		7	9	4	70	64.27	5.3		
289	890601	1800	32.0	22.6	8.1	7	7	3	70	66.88	5.0		
290	890601	2200	23.0	23.0		8	9	4		99.70	6.5		
291	890602	200	23.0	22.0		8	8	4		107.76	8.3		
292	890602	600	21.0	22.0		9	9	4	70	94.41	9.5		
293	890602	1000	25.0	23.0		8	8	3	65	84.00	9.8		
294	890602	1400	31.0	23.0	8.5	7	7	3	70	81.13	9.8		
295	890602	1800	33.0	23.0	8.3	7	7	3	60	91.18	10.4		
296	890602	2200	21.0	22.0		8	8	4		93.17	10.8		
297	890603	200	20.0	21.0	8.2	8	8	4		90.03	10.9		
298	890603	600	22.5	22.8	8.3	8	9	4	60	72.33	9.6		
299	890603	1000	27.0	23.0	8.1	7	8	4	60	72.57	7.4		
300	890603	1400	27.0	23.0	8.0	7	7	3	60	81.44	8.0		
301	890603	1800	31.0	23.0	8.1	7	7	3	65	76.20	7.6		
302	890603	2200	22.0	23.0	8.0	7	8	4		50.92	5.3		
303	890604	200	22.0	23.0		8	8	4		58.30	4.0		
304	890604	600	20.0	23.0	8.3	8	9	4	55	42.67	2.7		
305	890604	1000	26.0	23.0	8.0	8	8	4	65	42.97	2.3		

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
306	890604	1400	25.0	23.0	8.0	7	8	2	70	39.62	1.8		
307	890604	1800	29.0	23.0	8.1	7	8	2	60	46.02	0.5		
308	890604	2200	20.0	23.0	8.3	8	9	4			0.0		
309	890605	200	24.0	23.0		7	9	4			-0.1		
310	890605	600	20.0	23.0	7.9	8	10	4	60	47.24	-1.5		
311	890605	1000	30.0	24.0	8.0	8	9	4	65	42.98	-1.4		
312	890605	1400	30.0	24.5	8.0	7	8	4	60	60.44	-1.4		
313	890605	1800	26.0	24.0	8.2	7	7	3	70	51.51	-1.9		
314	890605	2200	23.0	24.0	8.0	8	9	4		51.82	-1.9		
315	890606	200	20.5	23.0	7.9	8	9	4		56.00	-0.4		
316	890606	600	21.0	23.5	8.4	8	9	4	5	49.99	-0.7		
317	890606	1000	25.0	23.0	8.2	8	9	4	20	51.51	-0.9		
318	890606	1400	26.0	23.5	8.1	7	9	4	25	51.51	-0.8		
319	890606	1800	24.5	23.5	8.4	8	9	5	40	49.68	-0.8		
320	890606	2200	23.0	23.5	8.4	7	9	5		49.68	-0.8		
321	890607	200	21.0	23.0	7.8	8	10	5		49.07	-0.8		
322	890607	600	20.0	23.0	8.1	8	10	5	50	47.55	-1.5		
323	890607	1000	22.5	23.5	8.2	7	9	5	50	51.20	-1.5		
324	890607	1400	25.5	24.0	8.4	7	9	4	60	43.28	-1.5		
325	890607	1800	21.0	24.0	8.1	8	10	4	60	49.68	-1.3		
326	890607	2200	20.0	23.0	8.1	7	10	5		66.75	0.2		
327	890608	200	21.0	23.0	8.0	7	10	5		73.32	0.2		
328	890608	600	19.0	23.0	7.9	8	9	5	50	70.42	3.2		
329	890608	1000	27.0	23.0	8.3	7	9	5	60	67.95	3.2		
330	890608	1400	29.0	24.0	8.4	7	9	4	70	81.44	3.9		
331	890608	1800	28.0	24.0	8.0	7	7	4	60	71.93	4.1		
332	890608	2200	22.0	23.0	8.2	7	9	5		76.47	4.3		
333	890609	200	23.0	23.5	8.2	7	10	5		73.32	4.3		
334	890609	600	21.0	23.0	8.3	8	10	5	60	75.13	4.6		
335	890609	1000	25.0	24.0	7.8	7	10	5	60	83.34	4.7		
336	890609	1400	23.0	24.0	8.2	7	10	4	65	80.21	4.7		
337	890609	1800	22.0	24.0	8.4	7	8	5	60	82.70	4.8		
338	890609	2200	21.0	24.0	8.3	7	10	5		77.03	4.8		
339	890610	200	22.0	23.5	8.2	7	9	5		75.39	4.8		

Table A-4. *continued*

PAGE	DATE	TIME	ATEMP	WTEMP	PH	DO	COND	TDS	SECCHI	WVEL	RSTAGE	SREVS	OREVS
340	890610	600	21.0	23.0	8.3	8	10	5	60	76.75	5.0		
341	890610	1000	24.0	24.5	8.0	7	10	4	65	65.45	4.8		
342	890610	1400	28.0	24.0	8.3	7	11	4	70	81.44	4.8		
343	890610	1800	26.0	24.5	8.1	7	7	4	70	70.88	4.8		
344	890610	2200	21.0	24.0	8.1	7	10	5		69.27	4.8		
345	890611	200									0.0		
346	890611	600	18.0	23.0	8.0	8	10	5	65	70.42	4.8		
347	890611	1000	22.0	23.0	8.2	7	9	4	65	72.82	4.8		
348	890611	1400	23.0	23.5	8.3	7	8	4	70	67.54	4.8		
349	890611	1800	24.0	24.0	8.2	8	8	5	70	64.73	4.8		
350	890611	2200	21.0	23.0	8.3	7	9	5		78.44	4.8		
351	890612	200	19.5	22.5	8.2	8	10	5		67.31	4.8		
352	890612	600	19.5	23.0	8.3	8	9	5	75	68.83	4.8		
353	890612	1000	22.0	23.0	8.2	7	9	4	70	68.17	4.8		
354	890612	1400	25.0	24.0	8.2	7	9	4	70	68.17	4.8		
355	890612	1800	27.0	24.0	8.2	7	7	4	70	66.88	4.8		
356	890612	2200	21.0	23.5	8.3	8	9	5			5.2		
357	890613	200	21.0	23.0	8.2	8	10	4			5.2		
358	890613	600	20.0	23.0	7.9	8	9	5	55	88.17	6.4		
359	890613	1000	27.5	24.0	7.9	7	8	4	65	85.34	8.8		
360	890613	1400	27.0	24.0	8.1	7	8	4	80	105.62	9.2		
361	890613	1800	27.0	24.0	8.0	8	8	5	70	95.25	9.4		
362	890613	2200	24.0	24.0	7.3	7	9	4		91.57	9.6		
363	890614	200	23.0	23.5	7.9	8	9	4		96.11	9.8		
364	890614	600	23.0	24.0	7.8	8	10	5	60	97.42	10.3		
365	890614	1000	25.0	24.0	7.6	7	8	4	65	84.00	10.3		
366	890614	1400	26.0	24.0	7.5	7	8	4	60	92.36	10.3		
367	890614	1800	30.0	24.5	7.9	7	7	4	70	92.77	10.4		
368	890614	2200	26.0	24.0	8.0	8	9	5		96.98	10.5		
369	890615	200	24.0	24.0	7.9	8	8	4		98.78	10.5		
370	890615	600	25.0	24.0	8.1	8	9	5	65	97.42	10.5		
371	890615	1000	27.0	24.0	7.3	7	8	4	65	89.27	10.3		

Table A-5. Striped bass egg enumeration and stage of development data collected at Barnhills Landing Roanoke River, NC, from 17 March to 15 April 1989.

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
1	890317	1437													
2	890323	1030													
3	890329	1043													
4	890406	1042	0	0	0	0									
5	890412	1035	0	0	0	0									
6	890414	1800													
7	890414	2200													
8	890415	600													
9	890415	1000													
10	890415	1800													
11	890416	1000	0	0	0	0									
12	890416	1400	0	1	0	0	0	0	0	0					
13	890416	1800	0	0	0	0									
14	890416	2200	0	0	0	0									
15	890417	200	0	0	0	0									
16	890417	600	0	0	0	0									
17	890417	1000	0	0	0	0									
18	890417	1400	0	0	0	0									
19	890417	1800	0	0	0	0									
20	890417	2200	0	0	0	0									
21	890418	200	0	0	0	0									
22	890418	600	0	0	0	0									
23	890418	1000	0	0	0	0									
24	890418	1400	0	0	0	0									
25	890418	1800	0	0	0	0									
26	890418	2200	0	0	0	0									
27	890419	200	0	0	0	0									
28	890419	600	0	0	0	0									
29	890419	1000	0	0	0	0									
30	890419	1400	0	0	0	0									
31	890419	1800	0	0	0	0									
32	890419	2200	0	0	0	0									
33	890420	200	0	0	0	0									

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
34	890420	600	0	0	0	0									
35	890420	1000	0	0	0	0									
36	890420	1400	0	0	0	0									
37	890420	1800	0	0	0	0									
38	890420	2200	0	0	0	0									
39	890421	200	0	0	0	0									
40	890421	600	0	0	0	0									
41	890421	1000	0	0	0	0									
42	890421	1400	0	0	0	0									
43	890421	1800	0	0	0	0									
44	890421	2200	0	0	0	2	0	0	0	2	2	0	0	0	0
45	890422	200	0	0	0	0									
46	890422	600	0	0	0	0									
47	890422	1000	0	0	0	0									
48	890422	1400	0	0	0	0									
49	890422	1800	0	0	0	0									
50	890422	2200	0	0	0	0									
51	890423	200	0	0	0	0									
52	890423	600	0	0	0	0									
53	890423	1000	0	0	0	0									
54	890423	1400	0	0	0	0									
55	890423	1800	0	0	0	0									
56	890423	2200	0	0	0	0									
57	890424	200													
58	890424	600	0	0	0	0									
59	890424	1000	0	0	0	0									
60	890424	1400	0	0	0	0									
61	890424	1800	0	0	0	0									
62	890424	2200	0	0	0	0									
63	890425	200	0	0	0	0									
64	890425	600	0	0	0	0									
65	890425	1000	0	0	0	0									
66	890425	1400	0	0	0	0									
67	890425	1800													

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
68	890425	2200													
69	890426	200													
70	890426	600													
71	890426	1000	0	0	0	1	0	0	0	1	1	0	0	0	0
72	890426	1400	0	0	0	0									
73	890426	1800	0	0	0	0									
74	890426	2200	0	0	0	0									
75	890427	200	0	0	0	0									
76	890427	600	0	0	0	0									
77	890427	1000													
78	890427	1400	0	0	0	0									
79	890427	1800	0	0	0	0									
80	890427	2200	0	0	0	0									
81	890428	200	0	0	0	0									
82	890428	600	3	5	5	9	0	1	2	6	9	0	0	0	0
83	890428	1000	8	7	17	22	5	2	8	11	26	0	0	0	0
84	890428	1400	5	3	6	0	0	0	4	0	4	0	0	0	0
85	890428	1800	0	0	0	0									
86	890428	2200	0	0	0	0									
87	890429	200	0	0	0	0									
88	890429	600	4	1	1	1	3	0	0	1	4	0	0	0	0
89	890429	1000	0	0	4	0	0	0	1	0	1	0	0	0	0
90	890429	1400	0	0	0	0									
91	890429	1800	4	4	3	5	1	2	2	2	7	0	0	0	0
92	890429	2200													
93	890430	200													
94	890430	600	8	13	20	15	4	8	8	6	26	0	0	0	0
95	890430	1000	3	19	4	0	2	14	1	0	17	0	0	0	0
96	890430	1400	9	2	7	5	3	1	1	2	7	0	0	0	0
97	890430	1800	1	2	0	5	1	2	0	2	4	1	0	0	0
98	890430	2200	7	4	6	15	7	4	3	10	24	0	0	0	0
99	890501	200													
100	890501	600	15	9	10	8	7	5	3	4	19	0	0	0	0
101	890501	1000	11	19	16	16	9	15	13	12	49	0	0	0	0

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
102	890501	1400	14	9	12	5	12	6	9	3	30	0	0	0	0
103	890501	1800	3	4			2	2			4	0	0	0	0
104	890501	2200	4	8	4	16	4	3	0	10	17	0	0	0	0
105	890502	200													
106	890502	600	14	15	11	5	6	4	7	1	18	0	0	0	0
107	890502	1000	4	12	11	17	3	9	7	6	25	0	0	0	0
108	890502	1400	4	3	1	7	1	1	0	3	5	0	0	0	0
109	890502	1800	3	4	3	4	2	4	2	2	10	0	0	0	0
110	890502	2200	1	0	0	0	0	0	0	0					
111	890503	200	0	0	0	3	0	0	0	3	3	0	0	0	0
112	890503	600	0	0	0	3	0	0	0	1	0	0	0	0	0
113	890503	1000	0	0	0	0									
114	890503	1400	0	0	0	0									
115	890503	1800	0	0	1	0	0	0	1	0	1	0	0	0	0
116	890503	2200	0	0	0	0									
117	890504	200	2	0	0	0	1	0	0	0	1	0	0	0	0
118	890504	600	2	3	0	2	1	1	0	0	2	0	0	0	0
119	890504	1000	0	0	0	1	0	0	0	0					
120	890504	1400	0	0	0	0									
121	890504	1800	0	0	0	1	0	0	0	0					
122	890504	2200	0	0	0	0									
123	890505	200	0	0	0	0									
124	890505	600	0	0	0	0									
125	890505	1000	0	0	0	0									
126	890505	1400	2	1	3	1	0	1	0	1	2	0	0	0	0
127	890505	1800	0	0	0	0									
128	890505	2200	0	0	0	0									
129	890506	200													
130	890506	600	0	0	1	0	0	0	0	0					
131	890506	1000	0	0	0	0									
132	890506	1400	0	0	0	0									
133	890506	1800	0	0	0	0									
134	890506	2200	0	0	0	0									
135	890507	200													

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
136	890507	600													
137	890507	1000	0	0	0	0									
138	890507	1400	0	0	0	0									
139	890507	1800	0	0	0	0									
140	890507	2200	0	0	0	0									
141	890508	200	0	0	0	0									
142	890508	600	0	0	0	0									
143	890508	1000	0	0	0	0									
144	890508	1400	0	0	0	0									
145	890508	1800	0	0	0	0									
146	890508	2200	0	0	0	0									
147	890509	200	0	0	0	0									
148	890509	600	0	0	0	0									
149	890509	1000	0	0	0	0									
150	890509	1400	0	0	0	0									
151	890509	1800	0	0	0	0									
152	890509	2200	0	0	0	0									
153	890510	200	0	0	0	0									
154	890510	600	0	0	0	0									
155	890510	1000	0	0	0	0									
156	890510	1400	0	0	0	0									
157	890510	1800	0	0	0	0									
158	890510	2200	0	0	0	0									
159	890511	200	0	0	0	0									
160	890511	600	0	0	0	0									
161	890511	1000	0	0	0	0									
162	890511	1400	0	0	0	0									
163	890511	1800	2	0	0	1	2	0	0	0	1	1	0	0	0
164	890511	2200	0	1	0	0	0	1	0	0	1	0	0	0	0
165	890512	200	0	0	0	0									
166	890512	600	0	0	0	0									
167	890512	1000	0	0	0	0									
168	890512	1400	0	0	0	0									
169	890512	1800	0	0	0	0									

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
170	890512	2200	0	0	0	0									
171	890513	200	0	0	0	0									
172	890513	600	0	0	0	0									
173	890513	1000	0	0	0	0									
174	890513	1400	0	0	0	0									
175	890513	1800	0	0	0	0									
176	890513	2200	0	0	0	0									
177	890514	200	0	0	0	0									
178	890514	600	0	0	0	0									
179	890514	1000	0	0	0	0									
180	890514	1400	0	0	0	0									
181	890514	1800	0	0	0	0									
182	890514	2200	0	0	0	0									
183	890515	200	0	0	0	0									
184	890515	600	0	0	0	0									
185	890515	1000	0	0	0	0									
186	890515	1400	0	0	0	0									
187	890515	1800	0	1	1	0	0	0	0	0					
188	890515	2200	0	0	0	0									
189	890516	200													
190	890516	600	0	0	0	0									
191	890516	1000	0	0	0	0									
192	890516	1400	0	0	0	0									
193	890516	1800	0	0	0	0									
194	890516	2200	0	0	0	0									
195	890517	200	0	0	0	0									
196	890517	600	0	0	0	0									
197	890517	1000	0	0	0	0									
198	890517	1400	0	0	0	0									
199	890517	1800	0	0	0	0									
200	890517	2200	0	0	0	0									
201	890518	200	0	0	0	0									
202	890518	600	0	0	0	0									
203	890518	1000	0	0	0	0									

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
204	890518	1400	0	0	2	0	0	0	2	0	2	0	0	0	0
205	890518	1800	0	1	2	1	0	1	1	0	2	0	0	0	0
206	890518	2200	0	3	0	0	0	0	0	0					
207	890519	200	0	0	0	0									
208	890519	600	0	0	1	8	0	0	1	5	6	0	0	0	0
209	890519	1000	0	2	1	0	0	2	0	0	2	0	0	0	0
210	890519	1400	3	0	5	1	2	0	3	0	5	0	0	0	0
211	890519	1800	0	5	0	3	0	0	0	2	2	0	0	0	0
212	890519	2200	2	5	0	1	0	4	0	1	5	0	0	0	0
213	890520	200	1	0	0	0	1	0	0	0	1	0	0	0	0
214	890520	600	2	2	5	3	1	0	2	2	5	0	0	0	0
215	890520	1000	5	3	5	2	2	1	2	1	6	0	0	0	0
216	890520	1400	2	12	0	3	0	9	0	0	9	0	0	0	0
217	890520	1800	4	1	3	1	2	0	1	0	3	0	0	0	0
218	890520	2200	2	2	0	7	2	0	0	4	6	0	0	0	0
219	890521	200	0	4	3	1	0	3	1	0	4	0	0	0	0
220	890521	600	0	3	1	5	0	1	1	3	5	0	0	0	0
221	890521	1000	4	9	22	29	1	4	10	20	35	0	0	0	0
222	890521	1400	23	28	28	35	5	6	6	13	29	1	0	0	0
223	890521	1800	2	8	5	8	1	1	1	0	3	0	0	0	0
224	890521	2200	1	1	3	1	0	1	1	1	3	0	0	0	0
225	890522	200	4	2	1	5	3	0	0	0	3	0	0	0	0
226	890522	600	39	11	19	51	10	7	6	23	46	0	0	0	0
227	890522	1000	18	43	45	41	5	27	17	9	58	0	0	0	0
228	890522	1400	9	14	28	10	2	6	8	3	19	0	0	0	0
229	890522	1800	18	14	9	15	1	3	0	6	10	0	0	0	0
230	890522	2200	6	5	5	9	1	3	2	1	7	0	0	0	0
231	890523	200	2	2	11	9	1	1	2	4	8	0	0	0	0
232	890523	600	183	93	103	361	117	35	36	140	328	0	0	0	0
233	890523	1000	98	42	66	140	36	19	27	55	137	0	0	0	0
234	890523	1400	41	83	55	53	21	29	21	17	87	1	0	0	0
235	890523	1800	34	8	4	17	8	7	3	4	22	0	0	0	0
236	890523	2200	11	33			4	17			20	1	0	0	0
237	890524	200	42	21	31	59	23	9	14	17	63	0	0	0	0

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
238	890524	600	81	88	90	78	45	52	57	60	210	4	0	0	0
239	890524	1000	86	79	83	48	69	59	61	40	225	4	0	0	0
240	890524	1400	16	65	29	32	4	14	9	21	48	0	0	0	0
241	890524	1800	7	2	6	9	1	1	1	7	10	0	0	0	0
242	890524	2200	0	0	4	6	0	0	0	3	3	0	0	0	0
243	890525	200	2	6	2	3	0	2	0	1	3	0	0	0	0
244	890525	600	22	15	13	10	9	7	4	5	25	0	0	0	0
245	890525	1000	3	6	9	7	0	2	5	4	11	0	0	0	0
246	890525	1400	8	11	21	16	3	5	9	1	18	0	0	0	0
247	890525	1800	1	5	3	5	0	1	1	3	5	0	0	0	0
248	890525	2200	0	0	3	0	0	0	0	0					
249	890526	200	5	7	9	5	0	0	2	3	5	0	0	0	0
250	890526	600	5	36	40	16	1	19	17	10	47	0	0	0	0
251	890526	1000	39	52			3	9			12	0	0	0	0
252	890526	1400	3	8	5	1	1	3	1	1	6	0	0	0	0
253	890526	1800	7	2	3	6	5	1	2	5	13	0	0	0	0
254	890526	2200	87	94	113	69	55	35	64	32	186	0	0	0	0
255	890527	200	168	247	163	196	45	84	33	65	227	0	0	0	0
256	890527	600	206	141	175	234	65	55	48	84	99	0	153	0	0
257	890527	1000	123	92	69	63	7	11	8	8	0	0	34	0	0
258	890527	1400	10	15	10	19	3	8	4	5	20	0	0	0	0
259	890527	1800	5	11	4	13	3	6	0	7	16	0	0	0	0
260	890527	2200	12	13	17	25	8	6	10	14	38	0	0	0	0
261	890528	200	18	44	55	21	7	19	11	6	43	0	0	0	0
262	890528	600	45	23	18	14	6	6	4	5	19	2	0	0	0
263	890528	1000	2	15	5	7	1	5	3	3	12	0	0	0	0
264	890528	1400	5	4	7	5	1	0	1	2	4	0	0	0	0
265	890528	1800	0	0	1	0	0	0	1	0	1	0	0	0	0
266	890528	2200	4	12	12	15	2	8	8	3	21	0	0	0	0
267	890529	200	9	17	4	24	5	8	1	11	25	0	0	0	0
268	890529	600	5	8	8	3	3	3	2	1	9	0	0	0	0
269	890529	1000	0	3	5	2	0	1	3	0	4	0	0	0	0
270	890529	1400	1	0	2	5	1	0	0	3	4	0	0	0	0
271	890529	1800	7	3	4	3	3	3	3	1	10	0	0	0	0

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
272	890529	2200	4	20	10	8	1	9	6	4	20	0	0	0	0
273	890530	200	10	13	16	14	7	3	7	5	22	0	0	0	0
274	890530	600	15	6	5	4	4	2	2	1	9	0	0	0	0
275	890530	1000	6	10	18	13	2	4	5	4	9	2	4	0	0
276	890530	1400	11	0	4	8	8	0	3	6	2	15	0	0	0
277	890530	1800	3	3	2	1	1	2	1	1	2	1	2	0	0
278	890530	2200	2	2	5	3	1	1	2	1	0	0	5	0	0
279	890531	200	30	35	24	56	16	23	11	27	72	5	0	0	0
280	890531	600	80	40	102	159	44	25	86	90	0	0	245	0	0
281	890531	1000	82	83	56	75	30	30	27	41	8	0	120	0	0
282	890531	1400	31	32	48	25	16	17	23	9	11	0	54	0	0
283	890531	1800	24	41	84	62	13	12	52	41	35	60	23	0	0
284	890531	2200	141	127	61	137	65	45	36	59	164	41	0	0	0
285	890601	200	53	71	72	75	22	23	49	33	127	0	0	0	0
286	890601	600	43	21	19	21	10	5	9	11	6	11	18	0	0
287	890601	1000	15	23	18	12	5	11	7	5	26	2	0	0	0
288	890601	1400	7	3	30	14	4	2	17	8	29	2	0	0	0
289	890601	1800	9	14	19	13	4	9	16	9	9	2	26	1	0
290	890601	2200	28	24	45	28	18	19	22	19	9	18	50	1	0
291	890602	200	9	6	7	15	1	2	2	6	9	2	0	0	0
292	890602	600	4	3	3	11	1	0	0	4	5	0	0	0	0
293	890602	1000	0	0	2	3	0	0	0	2	1	1	0	0	0
294	890602	1400	0	2	1	2	0	1	1	2	4	0	0	0	0
295	890602	1800	5	6	1	6	3	1	1	2	7	0	0	0	0
296	890602	2200	4	5	0	0	0	0	0	0					
297	890603	200	0	2	2	0	0	0	1	0	1	0	0	0	0
298	890603	600	2	3	1	5	0	0	0	1	1	0	0	0	0
299	890603	1000	0	0	0	0	0	0	0	0					
300	890603	1400	1	0	0	0	0	0	0	0					
301	890603	1800	0	0	0	0									
302	890603	2200	0	0	1	1	0	0	0	1	0	1	0	0	0
303	890604	200	1	1	2	3	1	0	0	3	3	0	0	1	0
304	890604	600	0	2	1	0	0	1	0	0	1	0	0	0	0
305	890604	1000	0	2	0	2	0	0	0	0					

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
306	890604	1400	3	4	3	1	1	4	2	0	7	0	0	0	0
307	890604	1800	3	5	7	10	2	5	6	8	0	9	12	0	0
308	890604	2200													
309	890605	200	3	10	12	3	2	6	7	2	2	8	7	0	0
310	890605	600	3	5	1	4	3	2	1	2	0	0	8	0	0
311	890605	1000	0	0	0	0									
312	890605	1400	0	0	0	0									
313	890605	1800	0	0	0	0									
314	890605	2200	0	1			0	1			0	0	1	0	0
315	890606	200	0	0											
316	890606	600	1	1	0	0	0	0	0	0					
317	890606	1000	0	0	1	0	0	0	1	0	0	0	1	0	0
318	890606	1400	0	0	0	0									
319	890606	1800	4	4	1	0	3	2	1	0	0	0	6	0	0
320	890606	2200	2	8	5	4	0	3	1	1	0	1	3	0	0
321	890607	200	1	3	0	0	0	3	0	0	0	0	3	0	0
322	890607	600	1	2	1	0	0	1	0	0	0	0	1	0	0
323	890607	1000	3	1	0	0	3	1	0	0	0	1	3	0	0
324	890607	1400	0	0	1	1	0	0	1	1	0	0	2	0	0
325	890607	1800	2	1	0	0	2	1	0	0	1	0	2	0	0
326	890607	2200	1	0	0	0	0	0	0	0					
327	890608	200	0	0	0	0									
328	890608	600	0	0	0	0									
329	890608	1000	0	1	0	0	0	0	0	0					
330	890608	1400	0	0	0	0									
331	890608	1800	0	0	0	0									
332	890608	2200	4	5	1	1	3	2	0	1	3	3	0	0	0
333	890609	200	1	0	1	1	1	0	0	1	0	0	2	0	0
334	890609	600	1	1	0	0	0	1	0	0	1	0	0	0	0
335	890609	1000	0	0	0	0									
336	890609	1400	0	0	0	0									
337	890609	1800	1	0	1	0	1	0	1	0	2	0	0	0	0
338	890609	2200	1	0	0	0	1	0	0	0	0	1	0	0	0
339	890610	200	0	0	0	0									

Table A-5. *continued*

PAGE	DATE	TIME	ASURF	BSURF	AOBL	BOBL	ASVIA	BSVIA	AOVIA	BOVIA	ST1	ST2	ST3	ST4	HATCH
340	890610	600	0	0	0	0									
341	890610	1000	0	0	0	0									
342	890610	1400	0	0	0	0									
343	890610	1800	0	0	0	0									
344	890610	2200	0	0	0	0									
345	890611	200													
346	890611	600	0	0	0	0									
347	890611	1000	0	0	0	0									
348	890611	1400	0	0	0	0									
349	890611	1800	0	0	0	0									
350	890611	2200	0	0	0	0									
351	890612	200	0	0	0	0									
352	890612	600	0	0	1	0	0	0	0	0					
353	890612	1000	0	0	0	0									
354	890612	1400	0	0	0	0									
355	890612	1800	0	0	0	0									
356	890612	2200													
357	890613	200													
358	890613	600	0	0	0	0									
359	890613	1000	0	0	0	0									
360	890613	1400	0	0	0	0									
361	890613	1800	0	0	0	0									
362	890613	2200	0	0	0	0									
363	890614	200	0	0	0	0									
364	890614	600	0	0	0	0									
365	890614	1000	0	0	0	0									
366	890614	1400	0	0	0	0									
367	890614	1800	0	0	0	0									
368	890614	2200	0	0	0	0									
369	890615	200	0	0	0	0									
370	890615	600	0	0	0	0									
371	890615	1000	0	0	0	0									

Table A-6. Roanoke River flow (cfs), and daily production and viability of striped bass eggs estimated by W.W. Hassler.

	1981			1982			1983		
Date	River flow	Totnum	Percent viable	River flow	Totnum	Percent viable	River flow	Totnum	Percent viable
415	2,280			2,310			21,100		
416	2,660			2,350			22,300		
417	2,280			2,340			25,300		
418	2,290			2,320			25,600		
419	2,260			2,560			25,400		
420	2,460			2,280			25,400		
421	2,250			2,270			25,500		
422	2,250			2,300			25,800		
423	2,240			2,300			25,900		
424	2,250			2,300			25,700		
425	2,260			2,310			26,100		
426	2,260			4,680			25,500		
427	2,250			6,200			25,600		
428	4,560			6,200			25,400		
429	6,130	14,807,849	26.81	6,240			25,500		
430	6,120	4,466,917	51.35	7,840			25,500		
501	6,110	1,450,291	41.66	7,100			25,700		
502	6,160	2,049,754	58.82	6,260			25,800		
503	6,160	850,841	57.14	9,740	9,689,224	62.50	25,800		
504	6,130	2,668,548	50.00	8,650	15,930,133	67.86	25,800		
505	6,170	4,234,870	48.57	11,100	12,677,068	72.50	25,900		
506	6,110	3,384,028	32.35	10,600	24,203,403	69.62	24,200	0	0.00
507	6,080	6,136,315	45.28	11,600	36,862,867	66.99	20,300	0	0.00
508	2,350	3,404,646	46.51	6,290	52,449,125	79.86	20,200	2,479,392	0.00
509	2,280	231,102,640	84.73	6,320	195,991,599	89.41	20,200	31,345,564	51.61
510	2,310	15,980,245	45.91	6,350	861,737,906	84.09	20,200	2,778,863	14.29
511	3,100	1,624,128	43.75	6,200	38,727,708	79.13	20,200	2,274,149	0.00
512	8,980	2,643,097	29.41	7,530	3,368,147	65.22	20,200	3,921,461	0.00
513	2,290	4,567,860	40.00	10,200	16,831,627	60.87	19,900	9,761,224	2.50
514	2,280	7,747,779	26.08	6,110	59,829,691	52.65	19,000	2,159,153	0.00
515	2,870	4,107,506	80.00	6,030	12,813,921	70.93	19,000	33,880,293	11.81
516	2,270	1,996,474	68.00	6,030	59,403,581	75.08	19,000	83,007,948	13.18
517	2,270	11,995,043	80.82	8,570	56,412,465	70.25	19,100	48,137,029	6.90

Table A-6. *continued*

Date	1981			1982			1983		
	River flow	Totnum	Percent viable	River flow	Totnum	Percent viable	River flow	Totnum	Percent viable
518	2,570	1,068,052	30.76	7,330	71,883,748	59.86	19,200	3,562,898	0.00
519	7,480	1,097,238	12.50	5,980	7,889,620	40.82	19,200	4,151,811	0.00
520	3,900	999,523	37.50	6,010	17,087,491	76.27	19,400	1,911,615	0.00
521	3,690	223,840	50.00	5,990	37,450,084	68.73	19,200	1,664,998	33.33
522	2,250	1,807,590	57.14	6,050	14,635,665	74.51	19,100	729,443	0.00
523	2,240	11,015,722	74.62	6,030	8,746,962	75.81	19,100	67,953,394	26.86
524	2,250	2,840,649	80.00	6,020	13,016,484	74.71	19,100	73,328,239	22.55
525	2,260	0	0.00	6,360	6,761,628	57.78	17,900	181,935,230	28.14
526	4,650	0	0.00	5,940	2,192,804	53.33	15,300	85,173,366	36.71
527	2,530	92,613	0.00	6,010	17,243,938	79.83	12,600	78,739,084	42.02
528	3,940	0	0.00	6,600	21,834,696	68.75	9,490	16,695,190	36.96
529	4,020			6,400	3,412,828	47.62	8,120	106,866,581	52.83
530	4,380			6,050	2,398,124	50.00	8,550	343,217,551	37.96
531	3,100			6,050	12,577,924	61.18	14,400	96,575,021	54.55
601	3,220			8,650	3,920,536	76.00	14,900	2,661,682	7.69
602	4,170			8,830	907,856	40.00	15,200	3,076,379	0.00
603	3,040			9,010			15,100	3,727,573	28.57
604	3,860			11,200			6,160	7,794,064	31.71
605	4,070			9,850			6,140	22,418,003	49.69
606	2,440			10,500			14,300	16,157,706	42.35
607	2,680			11,500			14,200	2,134,174	11.11
608	4,380			13,800			11,900	1,668,459	0.00
609	9,570			13,900			9,660	3,106,877	40.00
610	2,530			15,300			10,300	6,551,900	20.00
611	2,630			18,100			6,160	1,064,888	57.14
612	2,340			18,100			6,390	0	0.00
613	10,300			18,200			11,500		
614	10,600			18,100			6,330		
615	6,920			18,100			4,500		
Total eggs		344,364,058			1,698,888,853			1,352,611,202	

Table A-7. Roanoke River flow (cfs), and daily production and viability of striped bass eggs estimated by WRC.

Date	1981 Egg count	1981 Number/ 100m3	1981 Percent viable	1982 Egg count	1982 Number/ 100m3	1982 Percent viable	1983 Egg count	1983 Number/ 100m3	1983 Percent viable
415									
416									
417									
418									
419									
420				814	239.5	81.4			
421	682	219.2	84.0	68	19.8	88.2			
422	2	0.5	50.0	11	3.9	72.7			
423	0	0.0		7	2.9	71.4			
424	224	59.1	86.2	0	0.0		1	0.3	0.0
425				365	101.7	76.7	2	0.6	50.0
426	445	135.8	15.5	335	88.5	57.9	0	0.0	
427	123	36.8	71.5	20	8.9	20.0	0	0.0	
428	4260	979.0	68.5	235	109.9	29.8	4	1.1	25.0
429	9224	4444.0	79.4	9	3.2	55.6	0	0.0	
430	2336	974.3	66.7	12	3.9	100.0	0	0.0	
501	2083	993.7	76.9	29	12.6	55.2	21	5.8	42.9
502	87	43.9	58.6	101	45.9	53.5	5	1.4	40.0
503	537	246.6	58.1	857	219.8	58.0	11	3.5	45.5
504	194	88.7	61.9	165	45.4	70.3	34	7.9	26.5
505	159	48.1	50.9	249	64.4	68.7	21	5.9	14.3
506	1042	330.3	58.3	317	81.0	67.5	18	5.6	16.7
507	1117	349.4	67.7	1023	278.0	68.1	45	14.3	20.0
508	1019	320.6	57.3	468	140.0	78.6	28	9.3	10.7
509	471	148.4	58.2	3762	1059.1	80.1	166	48.8	15.7
510	6938	2208.3	56.4	23673	7624.9	78.6	16	5.7	0.0
511	3459	1090.9	70.6	479	2.3	73.3	21	7.3	14.3
512	76	25.5	57.9	64	3.8	75.0	12	4.5	0.0
513	255	144.1	65.5	164	7.6	68.3	33	12.6	21.2
514	445	428.4	87.4	742	343.6	56.2	16	6.0	25.0
515	1529	1285.7	82.1				159	42.5	15.7
516							339	93.8	6.5

Table A-7. *continued*

Date	1981			1982			1983		
	Egg count	Number/ 100m3	Percent viable	Egg count	Number/ 100m3	Percent viable	Egg count	Number/ 100m3	Percent viable
517							574	161.6	3.1
518							12	4.2	16.7
519							29	9.9	10.3
520							21	6.7	23.8
521							3	0.9	33.3
522							0	0.0	
523							479	112.9	29.6
524							730	158.7	24.7
525							2161	449.6	13.9
526							949	224.3	34.5
527							560	139.6	42.0
528							157	47.9	36.9
529							1221	357.1	64.0
530							4190	1171.1	514.6
531							746	301.1	57.6
601									
602									
603									
604									
605									
606									
607									
608									
609									
610									
611									
612									
613									
614									
615									
	36707			33969			12784		